Feature Extraction of Plant Leaf Based on Visual Consistency

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Abstract--**Feature extraction of plant leaf based on image processing technology has an great application prospect in plant taxonomy and intelligent agriculture and forestry production. In order to achieve feature data which can not only meet the automatic processing demands of computer but also be consistent with human understanding and determination on a leaf, a new idea on feature extraction named as feature extraction based on visual consistency (FEBVC) is presented. The main idea of FEBVC is conducting feature extraction in the same way as people describe an object. The key point of FEBVC is how to determine the direction in which to describe an object. FEBVC has been tried on shape feature extraction of plant leaf. Firstly, the plant leaf is rotated to a certain orientation with an improved Inertia Axis method according to human habit of observing an object. Then six shape feature parameters are designed to describe the shape of plant leaves according to human habit of describing an object. Many plant leaves with different shapes have been tested and the results show a good feasibility. FEBVC is very applicable to the establishment of intelligent expert systems.**

Keywords--plant leaf; feature extraction; visual consistency; shape; expert systems

I. INTRODUCTION

Leaf is one of the important organs of plant. Leaf features can be used to identify their category and living status. Feature extraction of plant leaf is useful to research on plant and guidance of agriculture and forestry production. The traditional feature extraction of plant leaf is mainly in manual way, which is of less efficient and in which many features are difficult to be quantified such as color, shape symmetry, etc. The development of image processing technology provides a convenient tool for feature extraction of plant leaf and many related work [1-7] have been conducted.

When designing feature parameters for plant leaf, researchers used to pay more attention to meeting the needs of computer automatic detection and identification and less to human perception needs. The feature parameters designed are not consistent with human habit of describing an object, which can be called a lack of visual consistency. When people see the feature data, it is difficult for them to imagine what the object is, in orther words, it is difficult for them to establish a visual contact between the data and the actual object. For example, leaf length is often defined as the farthest distance between two points on the leaf; the Long Axis is defined as the line segment between these two points. Such definitions are advisable to leaves with thin and long shape but not to other leaves because these leaves may have two or more Long Axis. When designing an agricultural expert system, whether it will be applied to plant taxonomy or guidance of agriculture and forestry production, a good consistency between data from computer and empirical data from experts is expected. Obviously, feature parameters which have been designed for plant leaf previously can not meet such requirement.

The feature parameters of plant leaf can be designed according to human perception habit in order to get such a consistency. The basic idea is placing the plant leaf in the orientation in which people is accustomed to observing and describing an object and then designing feature parameters along this orientation. Feature extraction in this way can not only resolve the problem mentioned above but also provides a new idea for feature extraction such as the symmetry description on shape, color and texture.

The new idea on feature extraction is named as feature extraction based on visual consistency (FEBVC). FEBVC is aiming at designing parameters which can bring data meeting the needs of both computer automatic processing and human visual perception. In order to explain FEBVC, shape feature extraction of plant leaf is introduced in a FEBVC way. It includes orientation correction and feature description. Tests have been carried out on leaves with different shape and the results are satisfactory.

II. METHODS

A. Image Acquisition

HP 4070 scanner has been used for image acquisition. There are two requirements as follows:

1) Place the leaf tip pointing at the top and the leafstalk pointing at the bottom before scanning. Such an orientation the leaf placed is consistent with the habit of people observing and describing the leaf. Because the operation is in manual way, it may be not accurate. In subsequent processing an only orientation of a specific leaf can be worked out in the process of Orientation Correction.

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2) Set a white paper as the background of the leaf. It leads to a simple background in the image acquired and the leaf can be found in the image easily if necessary.

Fig.1(a) is just a crude image acquired.

B. Image Pre-processing

Although a white paper is used as the background in image acquisition, the background in the image acquired is not uniform white. In order to find the leaf in the image easily, the background should be uniformed to the same white, which can be achieved according to the color difference between the plant leaf and the background.

A plant leaf is generally composed of leafstalk and lamina. As the lamina takes on most features of the leaf, feature extraction of plant leaf is mainly carried out on lamina. So the leafstalk need be removed from the image. The reason that the leafstalk has not been removed before image acquisition is that the leafstalk is helpful to the rough positioning of leaf. The leafstalk can be removed according to the width difference between leafstalk and lamina and the their locations in the image.

Fig.1(b) is the image after pre-processing.

C. Orientation Correction

People like to describe an object along a certain direction, in other words, rotate the object to an appropriate orientation visually and then describe it. In image acquisition the leaf is placed in manual way and in the image acquired the leaf position is random. The leaf in the image should be rotated to a certain orientation before feature extraction. For example, Lamina in Fig.1(b) is tilted to the right obviously. It is customary for people to rotate it to the left before describing it. The angle that the leaf should be rotated is defined as visual balance azimuth (VBA).

The VBA of a symmetrical figure is the angle between the symmetry axis and the vertical line through the centroid of the figure, namely, azimuth in vertical direction of the principal axis of the figure. It can be found using Inertia Axis method [8]. Many plant leaves have good symmetry and Inertia Axis method is applicable. But some plant leaves have less symmetry and Inertia Axis method can not get satisfied results. It is because Inertia Axis method has been designed based on the principle of mechanical balance but the goal of Orientation Correction is to meet a visual balance. The visual balance is associated with not only mechanical balance but also other factors such as shape, color and background. The leaf color is symmetrical along the main vein usually and the background is simple in our work. Therefore, only mechanical balance and shape factors need to be considered.

When a lamina meets the visual balance, it looks symmetrical in horizontal direction and balanced in vertical direction. When people observe an object, the potential reference point of visual balance is the point of intersection of the vertical line through the centroid of the object and the horizontal line through the lowest point of the object. The closer the point on the object is to the reference point, the less impact it has on the visual balance. According to this character, Inertia Axis method could be improved as follows:

1) Search the centroid of the lamina in the image.

2) Set the centroid as the origin to build the Cartesian coordinate system.

3) Rotate the lamina around the origin, record the angle in each rotation and calculate the relative inertia moment of the lamina after each rotation using formula (1).

$$m_\theta' = \sum_{i=1}^{m}\sum_{j=1}^{m} x_i^2 \frac{y_j - y_{\min}}{y_{\max} - y_{\min}} \qquad (1)$$

In (1) x_i and y_j is the coordinate of a point, y_{max} and y_{min} are the ordinates of the highest point and lowest point on lamina after each rotation.

4) The angle corresponding to the smallest relative inertia moment is the VBA of the lamina in the image.

Fig.1(c) is the result of Orientation Correction of Fig.1(b). It is obvious that the lamina is in a proper orientation along which people are accustomed to describing the lamina. Feature parameters designed along this orientation will be consistent with human habit of describing an object.

D. Feature Extractions

Six parameters have been designed to describe the shape feature of the lamina after Orientation Correction: Aspect Ratio, Vertical Eccentricity, Rectangularity, Convexity, Horizontal Symmetry and Shape Complexity.

Aspect Ratio is defined as the ratio of the height h to the width w of the enclosing rectangular of lamina. It describes how narrow a lamina is.

$$ar = h / w \qquad (2)$$

The height h of the enclosing rectangular of lamina is divided into two parts by a horizontal line through the centroid of the lamina. The height of the upper part is h_u and the height of the lower part is h_l. Vertical Eccentricity is defined as the ration of h_u to h_l. It describes the symmetry of lamina in vertical direction.

$$ve = h_u / h_l \qquad (3)$$

Rectangularity is defined as the area ratio of the convex hull to the enclosing rectangular of the lamina. It

(a) A crude image (b) Image after pre-processing (c) Image after Orientation Correction

Figure 1. A sample of image processing

describes the occupation of lamina in the plane.

$$rv = s_{ch} / s_{er} \qquad (4)$$

Convexity is defined as the area ratio of the lamina to its convex hull. It describes the convexity of the contour of lamina and shows an integrated feature of leaf base and leaf margin.

$$cv = s / s_{ch} \qquad (5)$$

Vertical line through the centroid of lamina divides the lamina into left part and right part. The area of the left is s_l and the area of the right is s_r. Horizontal Symmetry is defined as the ratio of s_l to s_r. It describes the symmetry of lamina in horizontal direction. Usually the plant lamina has a good Horizontal Symmetry and the value is close to 1. But some plant laminas do not have good Horizontal Symmetry due to the living environment, the nutrient, plant diseases, insect pests and so on, the values of which are far from 1.

$$hs = s_l / s_r \qquad (6)$$

Shape Complexity is calculated according to the area s and the perimeter c of the lamina. It describes the complexity of lamina contour.

$$sc = 4\pi s / c^2 \qquad (7)$$

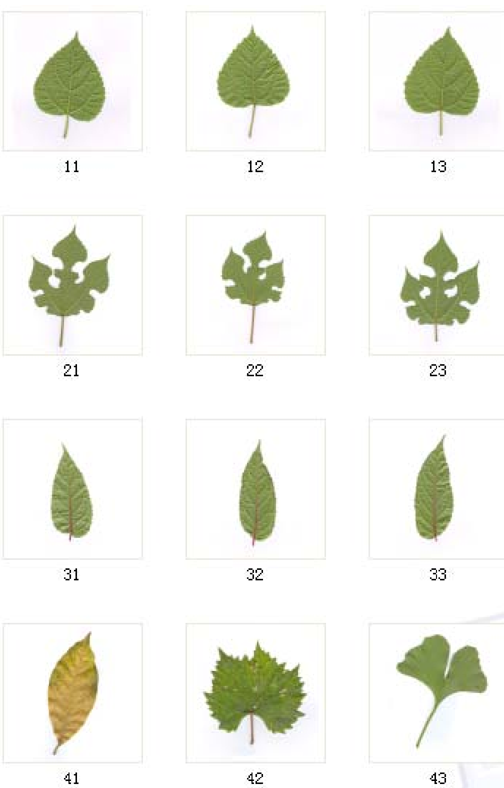

Figure 2. A group of test images

III. TEST AND ANALYSIS

The feature extraction algorithm has been programmed with Visual C++6.0. Many leaves with different shape have been tested. Here is a group of test. The test images are in Fig.2, which are from six plants. Table 1 shows the test results. Fig.3 presents comparisons of six parameters of each test lamina. According to the test results we can make the following analysis.

1) Feature data of Laminas from a same plant usually have a high coherence and those from different plants have significant differences. It indicates that the feature parameters designed could be applied on plant automatic identification.

2) Feature data of Laminas from a same plant have some slight difference. It reflects the individual differences among each lamina. It indicates that the feature parameters could be applied on plant growth monitoring, such as tracing the shape transformation due to nutrient deficiency.

IV. DISCUSSION

In our work image acquisition is implemented in a destructive way: pick a leaf from a plant and then acquire the image. It can facilitate the following processing such as finding the leaf in the image and lamina rough positioning.

Algorithm of Orientation Correction is designed for lamina. It can not be applied on the whole leaf, especially a leaf with a long leafstalk. If the Orientation Correction on the whole leaf is need, the VBA of the lamina could be used as that of the whole leaf.

Among all of the six parameters Convexity and Shape Complexity have no relations with orientation and the others are closely related with orientation. In actual applications, such as leaf image retrieval, only part of the six parameters may be needed.

V. CONCLUSION

In this paper a new idea on feature extraction of plant leaf is presented, which is named as feature extraction based on visual consistency (FEBVC). The design of FEBVC imitates the way people observe and describe an object. FEBVC could provide data which not only meet the computer needs of automatic detection and recognition but also are consistent with the human understanding and cognition on the object. It is applicable to both shape feature and other features, such as

TABLE I. TEST RESULTS

No.	Aspect Ratio	Vertical Eccentricity	Rectangularity	Convexity	Horizontal Symmetry	Shape Complexity
11	1.218	1.590	1.066	0.938	1.057	0.673
12	1.121	1.607	1.065	0.939	0.976	0.662
13	1.158	1.593	1.060	0.944	0.980	0.660
21	1.154	1.512	1.474	0.678	1.090	0.188
22	1.199	1.488	1.316	0.760	0.984	0.214
23	1.201	1.671	1.456	0.687	1.048	0.179
31	2.262	1.482	1.070	0.934	0.993	0.534
32	2.717	1.412	1.074	0.931	0.961	0.561
33	2.622	1.375	1.078	0.927	1.001	0.528
41	2.383	1.078	1.036	0.966	0.986	0.748
42	0.906	1.224	1.329	0.753	0.952	0.300
43	0.745	0.862	1.225	0.817	1.091	0.486

color feature and texture feature. Acquiring data based on FEBVC is conducive to the establishments of intelligent expert systems.

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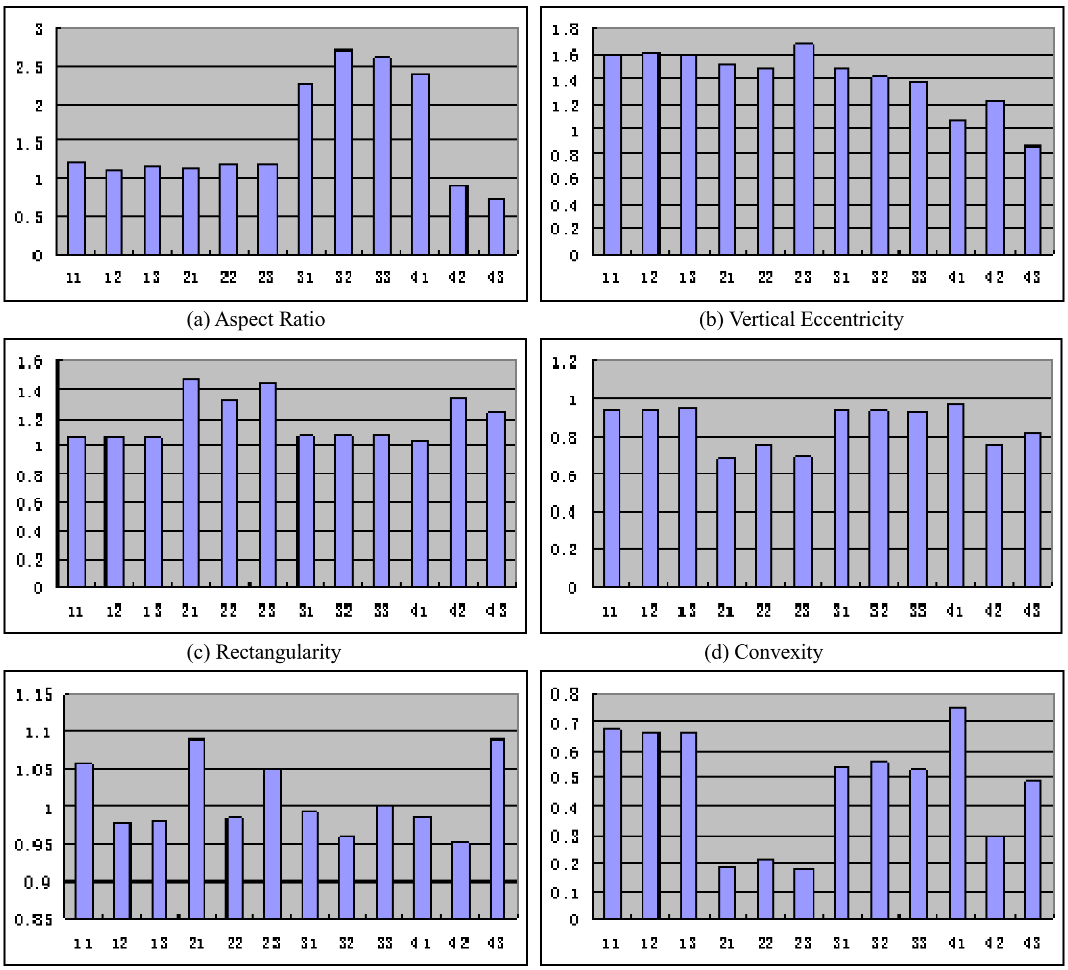

(a) Aspect Ratio

(b) Vertical Eccentricity

(c) Rectangularity

(d) Convexity

(e) Horizontal Symmetry

(f) Shape Complexity

Figure 1. Comparisons of feature data of each lamina