SbLRS: Shape based Leaf Retrieval System

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Abstract—In this paper, we present an effective image based retrieval system SbLRS (Shape based Leaf Retrieval System) for identification of plants on the basis of their leaves. In this system, a user gives query in the form of a digital leaf image (scanned against plain background) and the retrieval system matches it with its database and displays the names of those plants which have similar type of leaves. Several boundary based approaches has been implemented for matching. However, it is observed that our iterative retrieval approach SbLRS gives best matching results and the size of its database is also diminutive in comparison to other boundary based approaches.

Keywords—Plant recognition; leaf shape; image retrieval; Contour based image retrieval; shape recognition.

I. INTRODUCTION

There are millions of plants/trees existing in the ecosystem and we always feel the need of a system which can help us in identifying the plants. We, human beings, often try to identify a plant on the basis of its plant size, shape of its leaf, overall structure of leaves, its flower, etc. But, it can be observed that, most of the time, it is possible to identify a plant only by examining its leaf. Besides, leaf of a plant is easily available throughout the year and can be studied as a two-dimensional object. SbLRS is a system that does plant recognition based on shape of leaf.

There are various parameters available for CBIR (Content based Image Retrieval) approaches, like- shape, color and texture. It is well known that the color of most of the leaves is green and capturing the texture of leaves and differentiating among the textures of leaves is very difficult even for human beings. But, the shape and size of leaf varies from plant to plant and also leaf can be easily captured two-dimensional object. Shape representation approaches exploit the boundary details as in boundary based approaches and interior details as in region based retrieval approaches [1,2,3]. Some of the boundary based approaches include boundary chain code[5], fourier transform[8] and region based approaches include moment invariants [4], Zernike moments[11] and curvature scale space[12,13,14].In this paper, we have designed and developed a plant recognition system taking leaf image as input. We have implemented different boundary based approaches and compared the results. We observed that using combination of different approaches at different stages yield best results. The main contribution of this paper is that we propose an effective hierarchical model to ensure fast and effective retrieval. Its effectiveness is compared in terms of recall and precision with the available boundary based approaches. On the basis of experiments conducted, it is observed that our method requires comparatively less time to provide accurate results.

II. BOUNDARY BASED IMAGE RETRIEVAL APPROACHES

In this section, we briefly discuss various shape based image retrieval methods. These approaches were applied once the images were preprocessed as depicted in Figure 2. We have implemented and tested all the methods discussed below in our system for matching the leaves.

A. Centroid Distance Method: The distances of the boundary points, representing the image is computed with respect to the centroid of the image. The centroid is computed using Equation (1).

\[
\begin{align*}
M_{Ex} &= \frac{1}{m} \sum_{i=1}^{m} x_i \\
M_{Ey} &= \frac{1}{m} \sum_{i=1}^{m} y_i
\end{align*}
\]

(1)

where \(M_{Ex}\) defines centroid for x-point and \(M_{Ey}\) defines centroid for y point and \((x_i, y_i)\) are boundary coordinates representing the image and \((\bar{x}, \bar{y})\) are the centroid coordinates of the shape, computed using equation (1). The distance between two points is computed using Equation (2).

\[
CD = \sqrt{\sum_{i=1}^{m} (x_i - \bar{x})^2 + (y_i - \bar{y})^2}
\]

(2)

The dimension of the image representing the boundary points defines the dimension of the feature vector.
B. Tangential Angle Method: This method is used to measure the turning angle of the consecutive pixels[9]. The turning angle is computed using Equation (3).

\[
\tan \theta = m = \frac{y_{n+1} - y_n}{x_{n+1} - x_n}
\]  

(3)

This approach is quite significant as it captures the detailed curvature of the image irrespective of the orientation.

C. Angular Partitioning Method: This approach segments the image into four quadrants and counts the number of pixels in each quadrant. This method seems inappropriate because just the count of pixels per quadrant loses boundary information and it cannot be used for as the similarity criteria of shape.

D. Circular Partitioning Method: This approach works on the concept of concentric circles. The image is enclosed within the circle of largest diameter of the image. Thereby, four concentric circles are generated at equidistant spaces. The boundary information of the image is extracted and the number of boundary points lying in each of the concentric circles is identified.

E. Shape Matrix: This method captures the detailed pixel count of the image. The image is superimposed by a matrix of 4x6. The count of the number of pixels is maintained in each cell, corresponding to the grid [6, 7]. As compared to Circular Partitioning and Angular Partitioning, this method captures finer details of the image. The resultant matrix is affected by noise.

F. Quad Centroid Distance Variation Method: This method divides the image into four quadrants and computes the distances from centroid for each of the four quadrants [10]. Then, coefficient of variation is applied on the distance values and four values are generated. The coefficient of variation is defined using Equation (4),(5) and (6).

\[
\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2 / n}{n - 1}}
\]  

(5)

\[
\text{Coefficient of Variation (\%)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100
\]  

(6)

G. Mean-Max-Min (MMM) approach: This method is an extension of centroid distance approach. Here image is divided into four quadrants using centroid of the image as the origin. For each quadrant, distances from centroid are computed and from these values, maximum, minimum and average values are calculated. Hence, for complete image, only 12 (3 values per quadrants) values are stored as feature vectors.

III. SbLRS System

SbLRS software is a stand-alone application implemented in Java on Windows platform. It recognizes leaf images on the basis of shape parameters. The application was developed using NetBeans 7.3.1 and Oracle 10g. A database summing to about 500 leaves was created by considering approximately 15-20 leaves of each plant. These images were preprocessed and for each method, feature vectors were created. Fig.1 illustrates overall architecture of SbLRS. Fig. 2 depicts preprocessing stages for a given image before the feature vectors are computed.
Figure 1. System architecture of SbLRS

Query Image

Preprocess Image

Feature extraction method

Query Image Feature vectors

Image upload

Preprocess Image

Feature extraction method

Feature vector Database

Similarity Matching

Ranking retrieval images

Images generated after retrieval

Figure 2. Pre-processing stages for colored image

Load Image → Scale Image → Generate Binary Image → Identify edges of image

Store Boundary Coordinates

Identify starting point of image

Rotate Image → Remove noise

Boundary based image retrieval methods for matching

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Functionalities managed by administrator is depicted in Figure 3 and feature vectors for boundary based approaches can be generated by using interface as depicted in Fig. 4.

![Figure 3.Interface for Administrator](image1)

![Figure 4. Feature vectors methods for Administrator interface](image2)

User can query from SbLRS using various boundary based approaches as shown in fig. 5.

![Figure 5. Interface for User](image3)

![Figure 7.Database Snapshot](image4)

The iterative approach used in SbLRS is explained in Figure 6.

The database has been created by scanning the leaves against plain background. It contains multiple leaves of the same plant, approximately 15-20 leaves of each plant. In all, there are approximately 500 leaves. The leaves were scanned using flatbed scanner VistaScan Astra 3600. A snapshot of the leaves is depicted in figure 7.

IV. EXPERIMENTAL RESULTS

The queries were run on “Leaves Database” and results generated were compiled.

For measuring similarity in image retrieval, recall, precision and f-score were used. Recall is the ratio of the number of relevant retrieved images to number of all relevant images.

\[
Recall = \frac{\text{Number of relevant retrieved images}}{\text{Number of all relevant images}} \quad (7)
\]
Figure 6. Detailed Iterative Image Retrieval process in SbLRS
Precision is ratio of number of relevant retrieved images to number of retrieved images.

\[ \text{Precision} = \frac{\text{Number of relevant retrieved images}}{\text{Number of retrieved images}} \quad (8) \]

F-score is harmonic mean of recall and precision. It is referred as \( F_1 \) measure because it gives equal weightage to recall and precision.

\[ F \text{ score} = 2 \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (9) \]

Table 1 shows the average F1 score of various boundary based approaches for plant identification different threshold percentage:

<table>
<thead>
<tr>
<th>Threshold Percentage</th>
<th>Centroid Method</th>
<th>Tangential Angle</th>
<th>Angular Partitioning</th>
<th>Circular Partitioning</th>
<th>Shape Matrix</th>
<th>SbLRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td>3.00</td>
<td>2.28</td>
<td>1.31</td>
<td>1.32</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>85%</td>
<td>2.63</td>
<td>1.96</td>
<td>1.40</td>
<td>1.08</td>
<td>2.85</td>
<td>2.81</td>
</tr>
<tr>
<td>80%</td>
<td>2.19</td>
<td>1.68</td>
<td>1.16</td>
<td>0.97</td>
<td>2.81</td>
<td>2.81</td>
</tr>
<tr>
<td>75%</td>
<td>1.72</td>
<td>1.53</td>
<td>0.93</td>
<td>0.83</td>
<td>2.33</td>
<td>2.81</td>
</tr>
</tbody>
</table>

Table 2 shows the level of filtering of images at each subsequent level of iterative retrieval for our approach.

<table>
<thead>
<tr>
<th>Level</th>
<th>Stages</th>
<th>Reduction in DB size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clustering using Aspect Ratio</td>
<td>90%</td>
</tr>
<tr>
<td>2</td>
<td>QCDV and MMM approach</td>
<td>40%</td>
</tr>
<tr>
<td>3</td>
<td>Tangential Angle</td>
<td>68%</td>
</tr>
</tbody>
</table>

Figure 10 shows plot of precision versus recall at different threshold percentage: 90%, 85%, 80% and 75%.

Fig. 10 Precision versus recall plot at 90%, 85%, 80% and 75% for various boundary based approaches

Figure 11 shows precision versus recall comparison for the first five results generated when query was executed for various boundary based approaches.
V. CONCLUSIONS AND FUTURE WORK

Two plots for recall versus precision have been presented. Fig. 10 depicts comparison of precision versus recall for various boundary based approaches at different retrieval percentage. Fig 11 depicts comparison of precision versus recall for the first five results generated when different boundary based approaches were executed. It is observed that at 90%, shape matrix and centroid distance method performs equally well. But with reducing threshold percentage, the precision rate remains steady with improving recall rate but drops at 75% in shape matrix. Tangential angle approach shows linear improvement in recall rate and fall in precision rate. As compared to other boundary based approaches, our approach SbLRS maintains comparably satisfactory precision versus recall rate. Precision values are maintained stable values with improving recall rates. From figure 11, it is observed that precision versus recall rate is good for SbLRS for the first five leaves as compared against the boundary based approaches.

The important aspect to be focused of SbLRS is that because it uses iterative search approach, which causes reduction of database size at each consecutive level, hence ensuring faster results and reduces computation time. Though SbLRS provides satisfactory results when compared to other boundary based approaches, but still the results can be further improved by considering aspects of plant leaf. The work can be extended for region based image retrieval for understanding vein structure of the leaves.

REFERENCES