Classification of Bamboo Species by Fourier and Legendre Moment

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Abstract

Bamboo has being widely used as building material throughout the world. From traditional buildings to innovative architectural projects, bamboo has shown its suitability based on a combined low weight, high strength, beauty and durability. The properties of these species vary significantly. A successful application of bamboo in engineering firstly relies on the selection of a correct species. Therefore recognition of bamboo species is necessary before its efficient utilization. Species level identification of bamboos is a highly technical job done primarily by a systematic botanist based on morphological characteristics. However, recognition of the same can also be performed by computer. The bamboo Culm sheath shapes provide valuable data in identification of bamboo species. Automated recognition of bamboo has not yet been well established mainly due to lack of research in this area, non-availability and difficulty in obtaining the database. Using digital image processing and pattern recognition techniques, a supervised classification procedure of three different bamboo species has been developed.

In the proposed work, an automated bamboo species recognition system based on shape features of bamboo Culm sheath has been developed using Fourier and Legendre moment classifier. A confusion matrix is created to quantify the class wise and the classifier accuracy. The performance of the classifier is compared based on the classifier accuracy and classwise accuracy. It is concluded the Fourier moment have significantly good results than the Legendre moment. The system can eliminate the need for laborious human recognition method requiring a plant taxonomist. The results obtained shows considerable recognition accuracy proving that the techniques used is suitable to be implemented for commercial purposes.

Keywords: *Culm Sheath, Legendre Moment, Fourier Moment, Bamboo*

1. Introduction

Automatic recognition of plant species is a very challenging problem in area of pattern recognition, computer vision, plant taxonomy, and ecology. A reliable and accurate plant species recognition system will be beneficial to various sectors of business and community including plant resource management and education in taxonomy and biology. Few dicot plants can be identified through their leaves. The color and texture features of leaf image can also be considered for plant classification, but the shape features is more reliable because most of the leaves are green in color and their textures features are also very similar. The problem exists in identification of monocots especially the bamboos as they cannot be identified through their leaves and their flowering takes place after several years. Thus, the only part readily available for its identification is culm sheath.

Bamboos are used in construction, agricultural implements, horticultural pursuits, fishing industry, basket making, and paper & pulp. Some species are edible while others are strongly poisonous. In the modern context when forest cover is fast depleting and availability of wood is becoming scarce, the research and development undertaken in past few decades have established and amply demonstrated that several species of bamboo could be a viable substitute of wood. Through industrial processing composite materials are produced from this group, accordingly more plantation or production of good quality bamboo is to be done. The Bamboos have about 1200–1500 species with many species yet to be discovered or better documented. In order to assess the value of particular bamboo species it is necessary first to be able to identify them accurately [2]. The identification can be done mainly by a systematic botanist with a long experience in this field. The proposed study is aimed to eliminate the need for laborious human recognition method requiring a plant taxonomist, for identification of bamboos. Adopting this technique, a central management database system can be later developed that helps in identification of Bamboo species

In order to find an image from a database, the image has to be described by some features. Shape is an important visual feature for describing an object. Several techniques exist in literature for shape description [13, 23]. Shape descriptors are broadly categorized into two groups: contour-based and region-based shape descriptors. The region-based descriptors consider whole area of the object while contour-based descriptors concentrate merely on the boundary lines. Moments and functions of moments have been utilized as pattern features to achieve invariant recognition of 2-D image patterns. Legendre moments (LM) make use of Legendre polynomials.

The region based approached is used by many researcher. The image processing and probabilistic neural network techniques [19] classified the plant using their leaves features .The SOM is used for classification of leaf by geometric and texture feature of leaf.[28].The machine learning based SVM techniques introduced [11] color and texture features to recognize plant leaf image. The computer vision also plays a major role for shape classification. The SVM-BDT techniques is compared with Fourier moment and probabilistic neural network [20]in the case of plant classification by leaf shape using geometrical, morphological and moment based features. The Fourier moment is a contour based approach applied to the boundary co-ordinate of an object and expressed as complex numbers. [8] Fourier transform theory [4] has played a major role in image processing for many years. It is a commonly used tool in all types of signal processing and is defined both for one and two-dimensional functions. It has a wide range of applications in image processing. [15, 5, 7 9, 14, 16] and continues to be a topic of interest in theoretical as well as applied work in this field. Fourier transforms can be used in image enhancement, restoration, encoding and description. The values produced by the Fourier transformation of a given image represent the shape of the object in the frequency domain [24]. The lower frequency descriptors store the information about the general shape and the higher frequency descriptors store the information about the smaller details of the image. Therefore, the lower frequency components of the Fourier descriptor define the rough shape of the original object. The two moment techniques *viz* central moment and Legendre moment is used for classification of plant leaves and reported that Legendre moment has good accuracy than central moment [18]. The Fourier descriptors (FD) for hand posture recognition in a vision-based approach [3] The Fourier descriptor as a similarity measure and support vector machine for pattern classifier for a large scale database [25]. The generic Fourier descriptor is used for retrieval and classification of various shapes [26]. A set of moment invariants using a nonlinear combination based on normalized central moments is introduced for shape recognition [6]. The three kinds of moments Geometrical, Zernike and Legendre Moments have been evaluated for classifying 3D object images using Nearest Neighbor classifier [28].

In the proposed work, retrieval and classification of shape feature of culm sheath is employing Legendre moment and Fourier moment to classifying bamboo plant species has been worked out. Through image processing and Fourier moment classifier the proposed work is carried out for classifying bamboo of three different species *viz Bambussa Vulgaris, Bambussa Balcooa and Bambussa Tulda* using the shape features of culm sheath (modified leaf of bamboo).

1.1 Identifying Bamboos

To identify bamboo species the most important part of the plant, readily available are the Culm sheaths. These are protective sheaths around the stems (the stem is called a Culm in all grasses), see Figure 1. In the earliest stages of growth, the sheath completely surrounds and protects the new shoot. Later on, the sheath dries up and in most bamboos, eventually falls away. The sheaths are attached at the nodes, opening on alternate sides of the Culm. Culm sheath is a modified leaf in a bamboo culm, which generally consists of a blade, a large sheath, ligule and two auricles. The top of the Culm sheath is like a projecting tongue in the centre called the ligule, and ears on each side are called auricles. The shape and size of the auricles, shape, length and the type of edge on the ligule are also important part for identification. The blade of the Culm sheath is a modified leaf. Its shape, whether it has hairs on the back or around the base, whether it is erect or bent backwards (reflexed), and whether it falls off early (deciduous), or will remain attached (persistent), are also all important. The Culm sheath is both protective and also thickened so that it can support the soft, weak elongating Culm internode. It is usually deciduous, revealing the normally green Culm internode inside. Culm sheaths are the most important part of a bamboo for identifying different species. (Bamboo identification www.google.com)

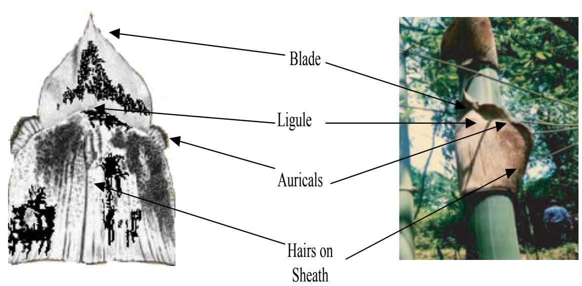
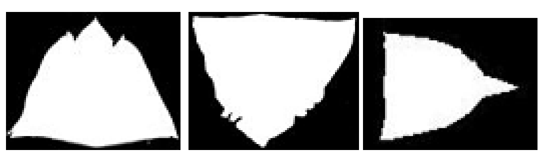


Figure 1. Culm Sheath

2. Method and Methodology

Culm sheath of three different species of bamboos viz. *Bambusa vulgaris, Bambusa tulda, Bambusa* balcoa is collected from the Bambusetum of *Forest Research Institute*, Dehradun. Culm sheaths at the culm base are different from those higher up. They are broader and have shorter blades. To standardize descriptions, culm sheaths at eye-level on the large bamboos are taken. These are approximately ¼ of the way up the culm. Smaller bamboos are also treated in the same manner, culm sheaths from ¼ of the way up the culm from the base being described. New culm sheaths show the features of the species best. Older sheaths often have parts that are missing or have rotted away, especially in hotter areas, and for this reason as per plant taxonomists bamboos are easiest to identify in the late summer and autumn (Charis Stepleton 1994).Collection of culm sheaths in good condition is important for further studies on automation. Culm sheath from bamboo plant was removed with a sharp knife or blade because it is very hard when it is green. The leaves were packed inside a rolled culm sheath, and a series of culm sheaths were rolled together and tied firmly. The outer sheaths protected the delicate parts such as auricles and blades of those at the centre. Collections were never placed into plastic bags as they develop moulds very rapidly. In the lab the sheath were then cleaned to remove hairs from the surface of the sheath. The same was then pressed with a heavy weight of plane object to straighten the Culm sheath. In whole procedure some culm sheath got broken while removing/cleaning the hair, some developed cracks in vertical direction; therefore problem to scan the actual boundary of the samples Culm sheath was faced.

Since the image database of the culm sheath is not available from any other source, therefore the image database is created by collecting the samples of three species of bamboo Culm sheaths from the Bamboosetum of *Forest Research Institute Dehradun*. Each species has 4 samples, so that total 12 samples are used to determine both intraspecific and interspecific variation. The Culm sheath is laid on a white sheet and then captured the image using a high resolution camera from a distance of approximately 3 feet from the ground level. Two procedures are followed to capture the image of sheath, the smaller sheath through scanner and the large sheath through camera wizard. By applying image processing the colored image is converted into gray level then in binary images using thresholding method and the output image is a binary image in which the leaf object are numerically displayed with 1 and the background is with 0.The sample threshold images of three classes are shown in Figure 2 (a, b, c)



a b c

Figure 2. Sample Threshold Images of Bamboo Culm Sheath (a) Bambussa vulgaris,(b) Bambussa Tulda,(c) Bambussa Balboa

3. Classification Method

3.1 Fourier Moment

In order to calculate the Fourier moments of an image, the centroid of the image is calculated. Rays are now drawn emanating from the centroid towards the boundary. The distance of the centroid from the point of intersection of the rays on the boundary of the image is calculated for each ray and stored. This sequence of lengths is periodic in nature since after every 2π radians the same ray is reached. For this periodic sequence Discrete Fourier Transform (DFT) is calculated. The sequence of radial distances for different images would yield different periodic signals, and therefore different DFTs. Calculation of DFT of the sequence of radial distances makes these moments invariant to rotation since shifting of a sequence or equivalently rotation of an image, corresponds to multiplication of the DFT by an imaginary exponential term, which does not affect its magnitude. A diagram depicting the radial distances and angles selected for calculate the Fourier moment of an irregular shape is shown in Figure 3

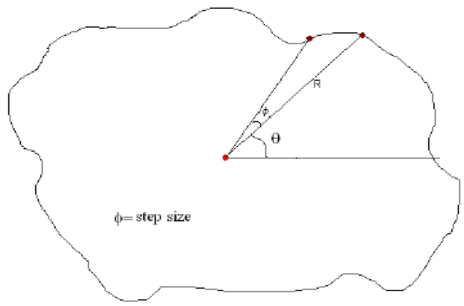


Figure 3. Radial Distance and Angle

The angle between two successive rays can be varied to increase or decrease number of points in the sequence. By decreasing the angular step more number of points would be extracted which would improve the resolving power of the Fourier moments.

The first step in computation of Fourier moments is to find out the boundary of the image. These boundary pixels are used to calculate the centroid of the image. The angle of all boundary points is calculated assuming the origin at the centroid and stored in a vector. Now a loop is used to generate angles, say *angle1*, from *0* degrees to *360* degrees with a step of *360/512*. For each angle generated by this loop, the closest angle from among the stored angle vector values is found. Since each of the angles stored in the angle vector correspond to boundary pixel, so the boundary pixel at an angle of *angle1* is determined. Now the distance of this pixel was calculated from the centroid. This is done for all pixels obtained from the previous steps. This resulted in a sequence of numbers representing the shape of the figure. 512 point FFT calculated on this sequence of radial distances to yield 512 Fourier moments.

3.2 Legendre Moment

Moments with Legendre polynomials as kernel function, denoted as Legendre moments, are first introduced by Teague. Legendre moments use the Legendre polynomials as their basis functions. Legendre moments have near zero redundancy so that the moments correspond to independent characteristics of the image. Legendre polynomials $P_n(x)$ are defined by

$$P_n(x) = \frac{1}{2^n} \sum_{m=0}^{n/2} (-1)^m \frac{(2n-2m)}{m!(n-m)!(n-2m)!} x^{(n-2m)} \quad (5)$$

The Legendre polynomials are orthogonal over the range $-1 \leq x \leq 1$. The expression may be simplified to

$$P_n(x) = \frac{1}{2^n} \sum_{k=0}^{n} c_{nk} x^k \quad (6)$$

where, Legendre coefficients are

$$C_{nk} = (-1)^{(n-k)/2} \frac{1}{2^n} \frac{(n+k)!}{[(n-k)/2]!\{(n+k)/2]!k!} \quad n-k = even\ldots \quad (7)$$

The orthogonality condition satisfied by Legendre polynomials is:

$$\int_{-1}^{1} p_p(x) p_q(x) dx = \begin{cases} 0. & p \neq q \\ \frac{2}{2p+1} & p = q \end{cases} \quad (8)$$

Teague utilized Legendre polynomials $P_n(x)$ as a moment basis set and defined the orthogonal Legendre moments L_{pq} as:

$$L_{pq} = \frac{(2p+1)(2q+1)}{4} \int_{-1}^{1} \int_{-1}^{1} P_p(x) P_q(y) f(x,y) dxdy \quad (9)$$

For the moments to be orthogonal the image must be scaled to $-1 \leq (x,y) \leq 1$. The corresponding set of Legendre moments for digital image is defined as:

$$\lambda_{nm} = \frac{(2n+1)(2m+1)}{(N-1)^2} \sum_{i=1}^{N} \sum_{j=1}^{N} P_n(x_i) P_m(y_j) f(i,j) \quad (10)$$

Where, a discrete image of size NxN is assumed. P(x) denotes the Legendre polynomials as defined earlier and *f(i,j)* is the intensity function for a discrete gray level image. In case of binary image it can assume only two values:1 or 0. Also, $x_i=(2i-N-1)/(N-1)$ and $y_j=(2j-N-1)/(N-1)$.

For reconstruction of an image from a truncated series of Legendre moments, the following expression is used

$$\lambda_{nm} = \sum_{n} \sum_{n} \lambda_{nm} P_n(x_i) P_m(y_j) f(i,j) \quad (11)$$

3.3 Computing Invariant Legendre Moments

The Legendre moments computed above are neither scale nor rotation invariant. However in order for Legendre moments to be useful for Culm Sheath classification, they are required to be scale and rotationally invariant. However it is impossible to make Legendre moments rotationally invariant. Therefore a different approach for the calculation of Legendre moments is used. This approach used from the invariant central moments to arrive at invariant Legendre moments through a mathematical relationship expressed below

$$L_{pq} = \frac{(2p+1)(2q+1)}{4} \sum_{i=0}^{|p/2|} \sum_{j=0}^{|q/2|} B_{p,i} B_{q,j} \eta_{p-2i,q-2j} \quad (14)$$

Here $B_{p,i}$ and $B_{q,j}$ are coefficients of Legendre polynomials defined by

$$B_{p,i} = \frac{(-1)^p (2i-2p)!}{2^i p!(i-p)!(i-2p)!} \quad (15)$$

and

$$B_{p,i} = \frac{(-1)^q q(2j-2q)!}{2^j q!(j-q)!(j-2q)!} \quad (16)$$

The central moments used for the calculation of Legendre moments utilized the whole image and not just the boundary as described in the previous section. This process although time consuming but more efficient.

4. Experimental Results

Culm sheath of three different species of bamboos have been collected from the Bambusetum of Forest Research Institute, Dehradun. Twenty samples from each species are collected for both intraspecific and interspecific variation. The total 60 samples are used to developed the methodology, 30 samples are used for training and remaining 30 samples are used for testing.The culm sheath is laid on a white sheet and captured the image using a high resolution camera from a distance of approximately 3 feet from the ground level.

In Legendre moment a maximum order of moment 10 is calculated for the entire 60 samples, this resulted in a set of 66 moments for each sample. In case of Fourier moment 512 point FFT is calculated. Based on the calculated moment of each sample a mean value is find out for that class which is the nucleus value of that class. The samples belonging to one class would make a cluster around its nucleus. There would be three such clusters. For perfect classification results there should be no overlap between two clusters i.e. for each pair of clusters, image in the same cluster exhibit higher level of correlation whereas it is low between images in different clusters. Therefore by controlling the number of clusters, to a great extent, one could possibly control the degree of similarity among various images in a cluster. The maximum distance of any cluster member from its nucleus must be less than the minimum distance of any cluster member from the other nucleus.

The quantification of the classifier is calculated by designing a confusion matrix shown in Table 2 and 3, This is a d x d matrix, The data at position (p,q) in the matrix corresponds to the number of samples of class p which got classified as class q. Thus all the diagonal elements correspond to correct classification while all off diagonal elements indicate classification errors. To determine the effectiveness of a classifier, all the diagonal elements are summed and divided by the sum of all elements of the matrix. This metric measured the overall classifier accuracy.

$$\text{Overall classifier accuracy} = \frac{\text{Number of correct samples}}{\text{TotalNumber of samples}}$$

Another important metric for a classifier is the class wise classification accuracy. In order to determine this, the diagonal element of the *kth* row, say d_k is taken and divided by the sum of all elements in the row; say q_k .The ratio $\frac{d_k}{q_k}$ gave a measure of how well the classifier performed for the k^{th} class. This ratio was measured for all the classes. Therefore at the end of this analysis there are two metrics for analyzing the relative performance of the classifiers: the overall classification accuracy and class wise classification accuracy.

This classification procedure is followed to classify the bamboo Culm sheath (leaves) images and the performance of the classifier is measured.

The average CPU time taken (seconds) during computation of the moments of leaves of each class is tabulated in Table 4, and shows that Legendre moment has much computation time as compare to Fourier moment, the average saving of time is 99.46%. The timing was measured on a machine running on Intel(R) Core 2 Duo CPU T5550 running @ 1.83GHz with a RAM of 3.00GB.The implementation was carried out in MATLAB R2006b.

The overall classification accuracy of the Fourier moment classifier is found to be 100% and Legendre moment is 90% which is shown by a graph in Figure 4. The class wise accuracy of both the classifier is compared and is shown in Table 1.The number of samples which are correctly classified are in case of Fourier moment and Legendre moment are shown in Table 2 and Table 3 by confusion matrix. All the diagonal elements are correct samples while all off diagonal elements are misclassification.

Table 1. Performance Analysis of Classification Accuracy

Class of bamboo Leaf	Fourier Classifier Accuracy%	Legendre Classifier Accuracy%
Class1	100	100
Class2	100	70
Class3	100	100
Average Accuracy	100	90

Table 2. Confusion Matrix of Fourier Classifier

Class	Class1	Class2	Class3
Class1	**10**	0	0
Class2	0	**10**	0
Class3	0	0	**10**

Table 3. Confusion Matrix of Legendre Classifier

Class	Class1	Class2	Class3
Class1	**10**	0	0
Class2	0	**7**	1
Class3	0	0	**10**

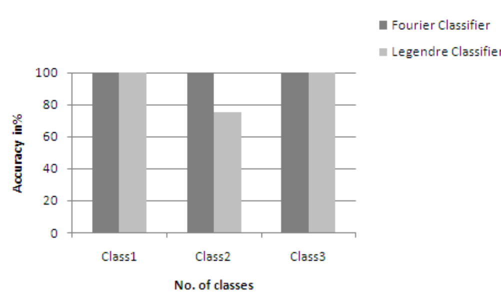


Figure 4. Performance Analysis of Classifiers Accuracy

Table 4. Timing Analyses for Fourier and Legendre Classifier

Classes of culm sheath	Fourier Classifier(msec)	Legendre Classifier(msec)
Class1	.0185	4.32
Class2	.0175	2.73
Class3	.0034	4.12
Average time	.0131	3.72

$$\text{Computation time saving in \%} = \frac{3.72 - .0131}{3.32}$$

$$= 99.46\%$$

5. Conclusion

A comparative study is carried out for shape classification using Fourier and Legendre moment techniques for a database of 60 Culm sheath shapes of three species of bamboos. An arbitrarily chosen shape is used for shape classification with respect to the whole database. In the case of Fourier Moment the radial distance and angle are used for similarity measure. It was observed that there is little variation in the values within class and large variation between the classes. In Legendre moment a maximum order of moment 10 is calculated this resulted in a set of 66 moments for each sample. The performance of both the classifier is calculated by class wise accuracy, total classification accuracy and time analysis of both the classifier. It is observed that Fourier moment classifier has significantly better accuracy than Legendre moment classifier. This set of moments is extremely easy to calculate and much less computationally intensive than the Legendre moments, it can save 99.46% time since they used only the boundary information of the images.

As a shape descriptor technique, the evidence to date is that Fourier moment are very good features to use when dealing with particular types of shapes. The aim of the proposed work is to investigate the usefulness of Fourier descriptors for the shape description for bamboo culm sheath. Thus, based on the above results it can be concluded that Fourier moment is one of the several techniques of object recognition that produces optimal results in bamboo culm sheath recognition.

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