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Object Identification using Wavelet Transform

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Abstract

Background/Objectives: Object identification in color images is a complex task, especially when the background and lighting conditions of the environment are uncontrolled. **Methods/Statistical Analysis:** This paper proposes an object identification algorithm to identify the light green tea leaves from the tea plants. **Findings:** In this paper we examine the wavelet transform, one of the most recent mathematical tools related to image processing, for identifying our desired object. Here, we concentrated on identifying the light green tea leaves. The paper is divided into two main parts. In the first part, we illustrated the compression for a color image, by using two different wavelets transforms i.e. the Haar wavelet and Integer wavelet transform (IWT). In this we have analyzed the behavior of these two wavelet transform with different tea leaves images and identified the most appropriate wavelet transform that can perform better process to compress the given color image. To analyses the performance of the wavelet transform with the color images, we calculated Peak Signal to Noise Ratio (PSNR) and compression ratio. The second part deals with Segmentation, which includes edge segmentation and clustering i.e. K-means. **Applications/Improvements:** The enhancement has been performed for edges. K-means clustering is used to separate the colors from the image, whereas edge based segmentation gives the shapes of the desired regions. Finally the light green tea leaves are identified by using above mentioned methods. These theoretical aspects are illustrated through MATLAB.

Keywords: Edge based segmentation and Edge enhancement, Haar, IWT, K-means clustering

1. Introduction

Camellia sinensis is the species of plant whose leaves and leaf buds are used to produce the popular beverage tea. The first person to drink tea was a man named, Shen Nung. During the mountain climbing, he became quite thirsty so he picked this leaf up and twisted the leaf with his fingers. The taste of the juice was quite bitter, so he felt that this leaf could have medicinal properties and could help quench thirst, when brewed. Thus, according to legend he was the first individual to drink tea. Tea plants produce abundant foliage, a camellia-like flower, and a berry, but only the smallest and youngest leaves are picked for tea-the two leaves and bud at the top of each young shoot. The young, light green leaves are preferably harvested for tea production; they have short white hairs on the underside. Older leaves are deeper green. Different leaf ages produce differing tea qualities, since their chemical compositions are different. The growth of new shoots, called a flush, can occur every week at lower altitudes but takes several weeks at higher ones. The new leaves are picked by hand by "tea pluckers". This hand picking is repeated every one to two weeks.

Object identification is often involved in many important real life applications such as biomedical image processing, remote sensing, wood species recognition, etc. Such situation has encouraged extensive researches to be conducted on images for object identification. Several algorithms are used nowadays for detecting an object in an image[1,2]. In this paper, we mainly concentrate for object identification by wavelet transform. Wavelet transforms have become

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one of the most important and powerful tools for image processing.

Wavelets provide a powerful and remarkably flexible set of tools for handling fundamental problems in science and engineering, such as audio de-noising, signal or image compression, object detection, fingerprint compression, image de-noising, image enhancement, image recognition, diagnostic heart trouble, speech recognition, etc., Waves are smooth, predictable and everlasting, whereas wavelets are of limited duration and irregular[3-5]. Wavelets allow complex information such as music, speech, images and patterns to be decomposed into elementary forms at different positions and scales and subsequently reconstructed. The Fourier transform is a useful tool to analyze the frequency components of the signal. However, if we take the Fourier transform over the whole time axis, we cannot tell at what instant a particular frequency rises. Short-Time Fourier Transform (STFT) uses a sliding window, which gives the information of both time and frequency. But still problem exists: The length of window limits the resolution in frequency. Wavelet transform seems to be a solution to the problem above. It is based on small wavelets with limited duration. It is a transform that provides the time-frequency representation simultaneously[6].

Wavelet transform is one of the best tools to determine where the low frequency and high frequency is. It involves in compression for decomposing the image into approximation and detail. The approximation sub image shows the general trend of pixel values, and the three detail sub images show the vertical, horizontal and diagonal details or changes in the image.

Image segmentation is an important task in image processing. It plays a vital role in many other fields such as robot vision, computer vision, object recognition and medical imaging. Segmentation includes histogram based technique, clustering based technique, edge based technique, contour based technique, thresholding based technique and region based technique and so on. Segmentation involves in partitioning an image into a number of homogeneous segments with respect to one or more characteristics and features, in general texture, shape, gray level intensity or color information[7].

Low contrast and poor quality are main problems in the images. Image Enhancement improves the quality (clarity) of an image for human viewing. It changes the original image into a more suitable form for human observation or computer analysis[8].

Tea leaves segmentation is an important task in vegetation. For tea preparation, only light green leaves are used. Identifying the disease affected leaves helps to prevent the spreading of diseases to other regions of the plants[9].

2. Compression

Compression is the process of representing information in a compact form. Number of bits required to represent the information in an image can be minimized by removing the redundancy present in it. Compression is a necessary and essential method for creating image files with manageable and transmittable sizes. In our paper, the compression is mainly done to get smooth regions (low sub band) from an image and to eliminate high frequency components which provides sharp edges[10-13].

The LL sub band contains a rough description of the original image and hence called the approximation sub band. The HH sub band contains the high-frequency components along the diagonals. The HL and LH images result from low-pass filtering and high-pass filtering. LH contains mostly the vertical detail information. HL represents the horizontal detail information. The sub bands HL, LH and HH are called the detail sub bands since they add the high-frequency detail to the approximation image[14].

2.1 Haar Transform

The Haar transform is one of the earliest transform proposed, whose distinctive feature is simple manual calculations. It is memory efficient, exactly reversible, fast and simple. As such the Haar transform technique shown in Figure 1 is widely used these days. The two important steps of Haar transform is averaging and differencing. The averaging process provides the Low Frequency (LL) information whereas the differencing process gives the detail information of an image (HH, HL and LH).

- Averaging: $A = \frac{x+y}{2}$ (1)
- Differencing: $D = \frac{x-y}{2}$ (2)

The above two equations implement the Discrete Wavelet Transform (DWT) of the Haar-wavelet transform.

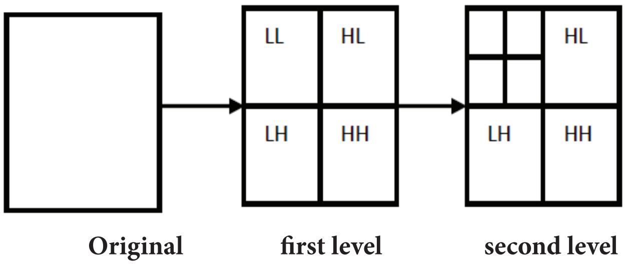


Figure 1. Haar decomposition levels.

2.1.1 Algorithm for Haar Transform

First Level:
For each row:

- Consider an image matrix with size of nxn.
- Find the average of each pair of samples. ($n/2$ averages)
- Find the difference of each pair of samples. ($n/2$ differences)
- Fill the first half of the array with averages.
- Fill the second half of the array with differences.

For each column:

- Find the average of each pair of samples. ($n/2$ averages)
- Find the difference of each pair of samples. ($n/2$ differences)
- Fill the first half of the array with averages.
- Fill the second half of the array with differences.

Next Levels

Repeat the same process for other levels. In this simulation, we worked with two level decomposition by changing an image with the size of 256x256 to the size of 64x64.

2.2. Integer Wavelet Transform

The transformation shown in Figure 2 is done via lifting steps, entirely in spatial domain. Using the lifting scheme we yield only integer wavelet- and scaling coefficients instead of floating point coefficients[5].

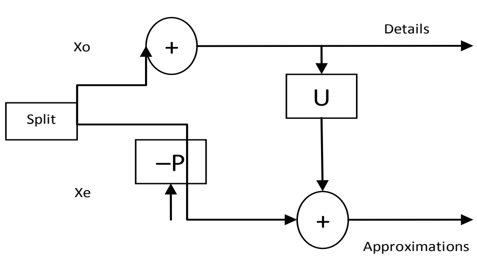


Figure 2. Integer wavelet transforms decomposition.

In lifting scheme, 3 steps are involved in order to compress the color image.

- Splitting
- Prediction
- Updated

$$P(S_i) = \left\lfloor \frac{1}{2}(S_i + S_{i+1})\frac{1}{2} \right\rfloor \quad (3)$$

$$U(D_i) = \left\lfloor \frac{1}{4}(D_{i-1} + D_i) + \frac{1}{2} \right\rfloor \quad (4)$$

2.2.1 Algorithm for IWT

- Divide the input data X into:

$$S_{i+1} = X_e = \{x_{2j}\}$$

Even data samples:

$$D_{i+1} = X_o = \{x_{2j+1}\}$$

Odd data samples:

- Predict X_e with X_o and replace by prediction error

$$D_{i+1} = D_{i+1} - P(S_{i+1})$$

- S_{i+1} is updated with D_{i+1} and replaced with the updated value

$$S_{i+1} = S_{i+1} + U(D_{i+1})$$

2.3 Performance Assessment Metrics

To measure the quality of compression by two wavelets such as Haar wavelet transform and Integer wavelet transform, we calculated compression ratio, mean square error and peak signal to noise ratio.

2.3.1 Compression Ratio

Let n_1 and n_2 denotes the number of information carrying units in original and compressed image respectively, therefore the Compression Ratio CR can be defined as

$$CR = \frac{n_1}{n_2} \quad (5)$$

2.3.2 Mean Square Error (MSE)

It is the cumulative squared error between original and recovered image.

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M \times N} \quad (6)$$

Where, I_1 is the original image and I_2 is the compressed image. The dimension of the images is M x N. Thus MSE should be as low as possible for effective compression.

2.3.3 Peak Signal to Noise Ratio (PSNR)

It is most commonly used as a measure of quality of reconstruction of lossy compression. It is the ratio between the maximum possible pixel value of an image and Mean square error.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad (7)$$

Where, R is the maximum possible pixel value of the image. PSNR should be as high as possible.

3. Segmentation

Image segmentation refers to the process of partitioning an image into groups of pixels which are homogeneous with respect to some criterion. Image segmentation is the first step in image analysis. It is a critical and essential component of image analysis system, is one of the most difficult tasks in image processing, and determines the quality of the final result of analysis[10]. In this project, we introduce a basic idea about color information and edge extraction to achieve the image segmentation.

3.1 K-Means Clustering

Clustering is a process of organizing the objects into groups based on its attributes. A cluster is therefore a collection of objects which are similar between them and the objects which are dissimilar belonging to other clusters. The most popular method is K-means clustering. Here, we are interested to segment light green leaves in tea plant and disease present in the leaves.

3.2 Algorithm for K-Means Clustering

- Select K points as the initial centroids.
- Assign all points to the closest centroid.
- Recompute the centroid of each cluster.
- Repeat steps 2 and 3 until the centroids don't change.

Here, we convert the RGB image into YIQ color space in order to distinguish the color information from the gray-scale information. In YIQ color space, the image mainly consist of three components namely luminance (Y), hue (I), and saturation (Q). All the color components present only in the "I" and "Q" components. We worked only in Q space[10].

3.3. Edge based Segmentation

Edges have been used extensively for content-based image retrieval. There are many simple edge operators like sobel, canny, log gaussian, perwitt, etc. These edge operators are used to find the edges of the binary images. But in our project without using all these operators we have detected the edges by using detail coefficients, by means of wavelet transform and enhance the edges[15-17].

4. Enhancement

An enhancement algorithm is one that yields a better-quality image for the purpose of some particular application which can be done by either suppressing the noise or increasing the image contrast and brightness. Image enhancement algorithms are employed to emphasized, sharpen or smoothen image features for display and analysis. The main contribution of enhancement in our paper is in differentiating the edge pixels from noise. High-pass filtered image mainly consists of edge information and also noise. In general, the pixel values of edges are lesser than the pixels of the noise. In order to eliminate the noisy pixels in an image, the edge information has to be enhanced. Edges in an image are mainly enhanced by means of the arbitrary pixel value[9].

The arbitrary pixel value $a\ (x,y)$ is calculated by taking the average between the minimum and he maximum pixel value present in the high-pass filtered image $f\,(x,y)$.

$$a(x,y) = (min\, f\,(x,y) + max\, f\,(x,y))\ /2 \quad (8)$$

Step 1: Select an arbitrary pixel a(x, y) from the high-pass filtered image and gains G1 and G2.
Step 2: If the pixel in the image is less than a(x, y), go to step 3. Else go to step 4.
Step 3: Multiply the pixel in image with gain G1.

Step 4: Multiply the pixel in image with gain G2, where G2<G1.
Step 5: Edge enhanced image.
Step 6: The enhanced image is converted into binary image.
Step 7: Perform necessary morphological operations.
Step 8: Divide the pixel labelled image from the morphologically operated image to get the desired region.
Step 9: Mark the desired region in the original image.

5. Proposed Algorithm

- Read the color image.
- Perform the image compression up to 2 level using Haar and Integer wavelet transform and analyses these wavelets by calculating the performance metrics such as PSNR and Compression ratio.
- The compressed image (Low pass filtered image) which is in RGB color space is converted to YIQ color space.
- The image which is in Q color space is given as an input to the K-means clustering process, in order to segment the image based on colors.
- High pass filtered image (LH, HL, HH), taken from compression step is enhanced in order to improve the contrast.
- Edge enhanced image is involved in morphological process to detect the edges of the leaves.

6. Simulation Results

The proposed algorithm in Figure 3 is mainly concentrated on identifying the desired object in a given color image as shown in Figure 5(a). Here we are interested for identifying five light green tea leaves present in the tea plants, because light green leaves are preferable for health and medical benefits. For identifying the light green tea leaves, initially we performed the compression because there is a drastic variation in the pixels at the edges which affects the color based segmentation. So we concentrated only on the approximation coefficients which provide the smoother regions without sharp edges. Therefore compression is done upto two levels to obtain the approximation coefficients and the detail coefficients, by using Haar wavelet transform as shown in Figure 4 and specifically in Figure 4 (b),(c) and also by integer wavelet transform as shown in Figure 5 and specifically in 5 (b),(c). Secondly the compressed image which contains only the approximation coefficients is given as an input to segmentation process, as shown in Figure 4 (d) and Figure 5 (d). The segmentation is based on K-means clustering technique to obtain the color information of an image. K-means clustering segments the image based on the colors. For that the image is converted from RGB to NTSC colour space as shown in the Figure 4 (e) and Figure 5 (e). Here we performed clustering upto K=3, the three clusters are represented by the pixel-labelled image as shown in the Figure 4 (f) and Figure 5 (f). Those three clusters are separately shown in the Figure 4 (g)-(i) and Figure 5 (g)-(i). Figure 4 (j) and Figure 5 (j) indicates the edges present in the original image that is obtained from the detailed coefficients by means of wavelet transform. Since the obtained edges have poor visual quality, the enhancement technique is performed to improve the contrast of those edges. The enhanced edge image is given in Figure 4 (k) and Figure 5 (k). For the purpose of identifying the green leaves the edge enhanced image is involved in morphological process (Figure 4 (l) and Figure 5 (l)) and by combining with pixel labelled image it results the shape segmented image (Figure 4 (m) and Figure 5 (m)). Now the shape segmented image is marked over the original image as shown in the Figure 4 (n) and Figure 5 (n), which shows the presence of the light green tea leaves in tea plants.

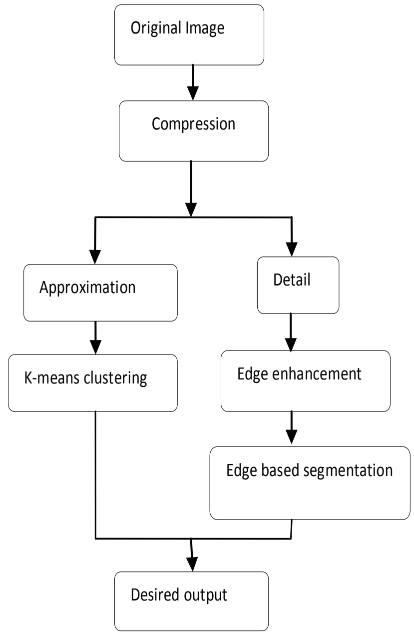


Figure 3. Flow chart for proposed algorithm.

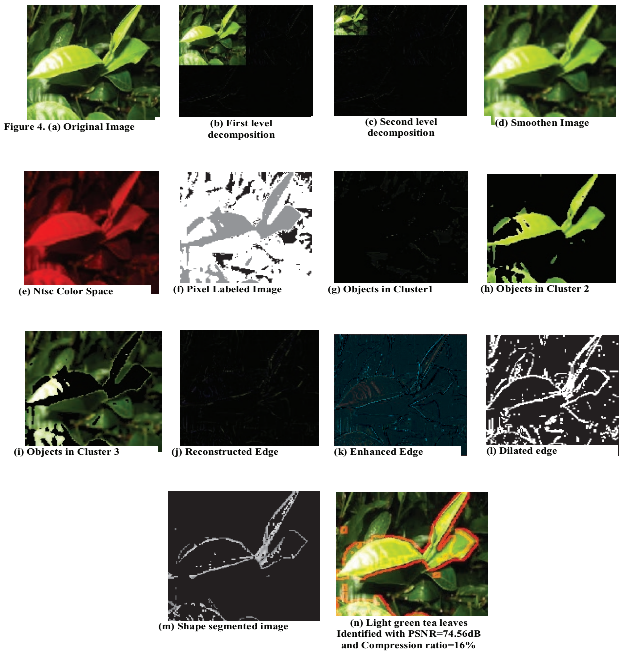


Figure 4. HAAR transform results.

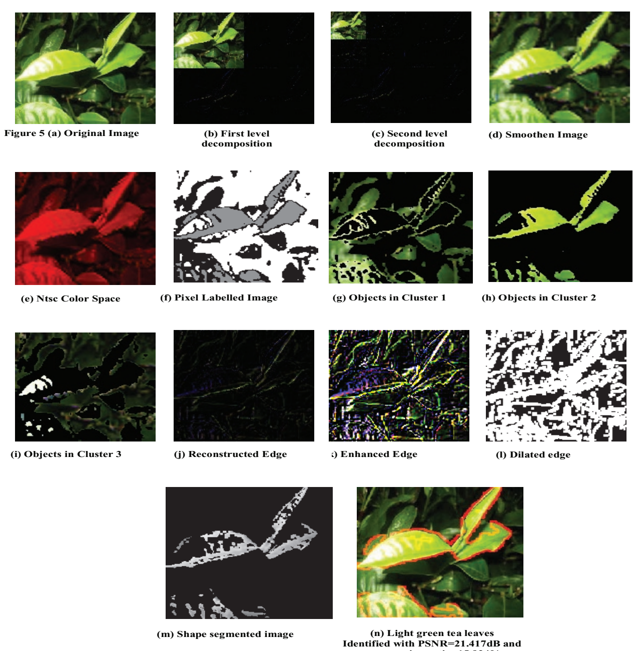
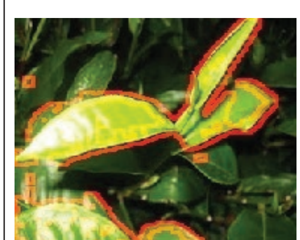
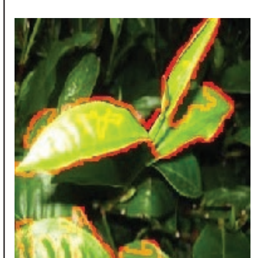


Figure 5. Integer waveform results.

7. Conclusion

This paper is mainly concentrated on identifying the desired object in a given color image. Since there is a drastic variation in the pixels at the edges which affects the color based segmentation, the compression is done to obtain only the low frequency components and to eliminate the high frequency components (sharp edge information). Secondly from the compressed image, the segmentation is done based on clustering technique to obtain the color information of an image. The high frequency components thus obtained by means of wavelet transform is used to get the edge information of a color image. Since the obtained edges have poor quality, the enhancement technique is performed to improve the contrast of those edges. After performing two methods mentioned above, the approximate color information of pixels and the information of boundaries are acquired. Now combining all these process we segmented the desired object from the original image. Thus the light green leaves from tea plant are easily identified. Even though both wavelets transforms produce good results for identifying the green tea leaves, by Table 1 comparing these two we concluded that integer wavelet transform provides a better result as compared with Haar wavelet transform.

Table 1. Analysis and comparison of wavelets

	Haar wavelet	Integer wavelet
1	First generation wavelet	Second generation wavelet
2	Works on integer, floating coefficients	Works only for integer coefficients
3	Averaging and differencing process	Spilt , predict and update process
4	PSNR is high	PSNR is low
5	Clustering is medium	Clustering is good
6	Enhanced edge has good visual quality	Enhanced edge has better visual quality
7	Identifies 5 light green tea leaves with small errors 	Identifies 5 light green tea leaves correctly 

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