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SHORT COMMUNICATION

Query Implementation Technique for Large Image Databases

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ABSTRACT

An image indexing technique using wavelet decomposition and clustering approach, which can be employed for retrieval of images from an image database, is presented. An algorithm incorporating image indexing on the clusters of regions has been developed. This method can be employed for region-based querying of image. The querying method described in this paper has applications in different domains, including graphic design, multimedia, geology, satellite imaging, medical imaging, defence, etc. Some experimental results obtained for different feature sets using Daubechies wavelet transform and Haar wavelet transform have been presented.

Keywords: Query implementation technique, wavelet decomposition, image retrieval, image indexing

1. INTRODUCTION

With the advancement in image processing techniques like graphic capabilities, speed of processor connected with prolific internet, have made possible for the users to access thousands of digital images easily. Applications on querying and searching of images can be found in different domains which include weather prediction, satellite imaging, data mining, medical imaging, multimedia, e-commerce, etc. Indexing of image databases, namely, the problem of retrieving the content information from images in response to queries, is a key problem underlying the operations of searching, browsing and summarising in image databases. In particular, it is an important problem in the online maintenance and management of a large volume of documents depicting texts, graphics and images.

The existing methods of retrieving such documents are either based on their textual contents for text documents or on the text tags associated with images. The basic approach to querying of an image has been referred to in a variety of ways which include query by content[1,2], query by example, similarity retrieval[3], etc. These types of querying can also be applied in conjunction with keyword-based querying or any other existing approach. In general, retrieving regions in images in response to a visual query is a difficult problem. A visual query usually depicts an object, and retrieving the relevant image from the database involves region selection and recognition, in which computationally-intensive search, based entirely on image features, is involved. In this paper, the problem of indexing of image databases using wavelet decompositions with clustering approach has been addressed.

Traditionally, this problem has been solved by computing a feature vector for each image by mapping all features to i-dimensional points in some space, and building an index of all feature vectors for fast retrieval. An appropriate distance function is defined for each pair of feature vectors, and given a query, the index structure returns the closest

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feature vectors to the query point. Typical approaches for solving this problem include, defining separate distance function for colour, shape, and texture, and combining these to get the overall result.

However, these approaches do not encode any spatial information in the feature vectors, and hence, scaled, rotated, and translated images cannot be handled. So, a system is desired that is robust wrt resolution changes, dithering effects, colour shifts, orientation, size, not only of the whole image, but its individual objects as well. In one of the existing methods, a single-feature vector is considered for the whole image. This method typically fails wrt scaling, rotation, and translation as a single-feature vector computed for the whole image cannot sufficiently capture the important properties of the individual objects. In another method, the image is decomposed into individual objects, and the feature vector, as a combination of features from each object, is stored. The drawback with this approach is that segmenting an image into regions is a very hard problem to solve.

A method which avoids segmentation of an image is proposed. Windows of varying sizes are considered, wavelet transform[4,5] is used for the extraction of feature and dimensionality reduction. An image distance metric, based on pair-wise comparison of the stored wavelet for each image, is used. As such, feature vectors would represent variable-sized windows. By comparing two-feature vectors, two different sized windows can be compared effectively, and the scaling problem can be eliminated. To keep the image processing procedure relatively fast, windows are considered as the elements of a fixed decomposition of each image.

2. PROPOSED TECHNIQUE

A method for searching an image database, using a query image that is similar to the intended target, is presented. The algorithm makes use of wavelet decomposition of the query and the database images. The coefficients of these decompositions are distilled into small feature vectors for each image. The paper describes how Haar wavelet decomposition of the query and the database images can be used to match a query. The algorithm uses non-standard 2-D Haar wavelet decompositions. One step for horizontal pairwise averaging and differencing on the pixel values in each row of the image is performed. In the next step, vertical pairwise averaging and differencing to each column of the result is performed. The above two steps are repeated recursively, only on the quadrant containing averages in both directions, to complete the transformation. The wavelet decompositions allow for very good approximation with just a few coefficients. This property has been exploited in the proposed algorithm. The coefficients of wavelet decomposition provide information that is independent of the original image resolution. Thus, a wavelet-based scheme allows the resolutions of the query and the target to be effectively decoupled. The image is broken into windows of different sizes ranging from $w_{min} \times w_{min}$ to $w_{max} \times w_{max}$. The significant coefficients from the lowest frequency band of the Haar wavelet transform have been used as the feature vector for each window. The windows in the image are then clustered using distance metric between pair of windows, and distance metric used is the Euclidean[6] distance. Each cluster thus contains a group of windows with similar characteristics. It identifies a region of the image with related pixel values. The query image is thus decomposed into a number of regions. Given a set of feature vectors $v = \{v_i, 1 \leq i \leq N\}$, the goal of the algorithm is to detect similar regions and to label the vectors based on the regions they belong to.

The idea here is to perform wavelet transform and efficiently represent high dimensional data, as well as connected component analysis on this representation. To retrieve database images which are similar to a query image, the distance between the query image and the database images will be computed (Euclidean distance is used to calculate the distance between the feature vector of the database images). The images with the distance smaller than the assumed threshold will be retrieved. The retrieval can be enhanced by searching only the related regions instead of the whole database, to efficiently narrow down the search. Arrays are built to keep all the neighbourhood information on each single dimension for each cluster of windows.

For i^{th} dimension, one orders the feature vector by i^{th} component and save it to i^{th} array. A hash function can be used to probe the index to find all regions in the database whose feature vectors are within $\in$ distance of any of the query's regions.

Algorithm

Input : *N* image feature vectors

Output: The set of all detected regions of clusters to

- Perform preprocessing of image by decomposing the image into regions
- Apply wavelet transform to get wavelet-based feature vectors
- Find the connected components (clusters) for regions
- Enter the regions consisting of clusters whose feature vectors lie within $\in$ distance into hash table.

The windows are clustered using the distance metric (Euclidean distance) between the pair of windows in the image. For each region of the query image a hash function is used to find all regions whose signature are within $\in$ distance of a region of the query. The results of image transformation after 2-D wavelet decompositions are shown in Fig.1.

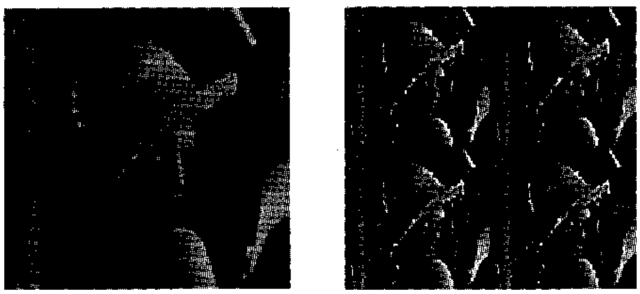

Figure 1. (a) Original lena image and (b) generated image

3. EXPERIMENTAL RESULTS

The approach is quite efficient for very large databases. The computational complexity of generating clusters is $O(N)$. The results are not affected by outliers. To study the impact of different feature sets on the effectiveness of retrieval, 10 query images of 128 x 128 pixels in size were choosen. The system processes queries, such as retrieve top *n* images that have the same texture as the query image. The effectiveness of retrieval is calculated in terms of retrieval rate. Retrieval rate of top *n* images is defined as

$$\text{Retrieval\_rate} = \text{Number of relevant images in top } n \text{ images}/n$$

The retrieval rates for values 10, 20, 30, 40 and 50 of *n* for the 10 query images have been calculated and then their average value is found. Table 1 shows the average retrieval rate of top *n* images for different feature sets giving the comparison with Daubechies wavelet transform and Haar wavelet transform.

Table 1. Average retrieval rate of top *n* images for different feature sets

	Feature set 1	Feature set 2	Feature set 3	Feature set 4
Daubechies	62.45	61.78	65.32	64.12
Haar	64.60	70.12	71.02	70.23

The execution time for the algorithm for computing feature vectors for window size varied from 2 × 2 pixels to 128 × 128 pixels has been plotted in Fig. 2. The points 2^i along the plot represent a window size of $2^i \times 2^i$, where x-axis is shown in logarithmic scale.

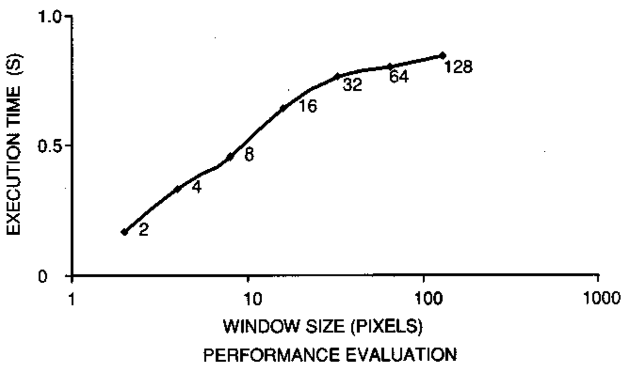

Figure 2. Plot of execution time for the algorithm for computing feature vectors for different window sizes.

4. DISCUSSIONS & FUTURE SCOPE

In the algorithm, it requires only a small amount of data to be stored for the image. Its utility depends, to a large extent, on the size of the image database. To evaluate the algorithm, TIFF images have been considered for gray scale images. An image querying method based on the Haar wavelet transform and the clustering approach is proposed. Feature vectors for $\log_2 w_{max}$ window sizes ranging from 2 to w_{max} have been computed. The execution time increases gradually as window size is increased. The processing time is proportional to the algorithm of window size. Threshold parameter $\in$ can be given as input to the algorithm. The execution time of the algorithm for different threshold values has been measured. The important factors that affect the performance of the algorithm are the image size and the window size. A good choice of the window size and the threshold value can greatly help in getting accurate results. Studies are being carried out to find more reasonable techniques of increasing the threshold dynamically. Also, the neural network techniques for learning the features of images are being explored. The future work will incorporate colour feature of the images.

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Contributors

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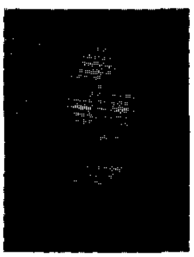

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