Indexing and Searching of image Data in Multimedia Databases

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ABSTRACT

This paper develops and studies new indexing techniques for content-based queries in images databases. Indexing is the key to providing sophisticated, accurate and fast searches for queries in image data. Various transforms were considered and evaluated with regard to their search effectiveness. It was found that indexing based on the hybrid of wavelet followed by the discrete cosine transform (DCT) performs better than any other known transforms.

The paper describes the implementation of the indexing scheme, and presents the findings of our extensive evaluation that was conducted to optimize (1) the choice of the wavelet, (2) the number of times the wavelet transform should be applied, and (3) the number of DCT coefficients taken as index. Furthermore, we compare the performance of our indexing scheme with other schemes. Our results show that our scheme has significantly higher performance.

Keywords: DCT, images, indexing, multimedia database, searching, wavelet.

1. INTRODUCTION

As modern computer technology advances at a rapid pace, multimedia systems have become an important part of our lives. Multimedia systems have been used in areas such as education, training, business, and entertainment. As a result of the extensive need for multimedia data search and the rapid growth in the computational power in computers, the processing of non-textual data such as images and videos have grown tremendously and are expected to have explosive growth in the coming years.

Searching for data, generally, is one of the most fundamental and widely performed operations, and has thus received considerable attention. The complicated nature and immense size of multimedia data make the search problem more difficult, and renders the traditional keyword-based indexing and search techniques inadequate.

An alternative approach for multimedia search is content-based indexing. Given a large database of images, our objective is to derive a scheme for the extraction of suitable features that index the database.

In this paper we consider transform-based indexing, and evaluate several transforms and transform-hybrids. We implement the most promising hybrid scheme, namely, the wavelet-DCT hybrid, and perform extensive experimental evaluation to optimize the parameters of the hybrid.

The paper is organized as follows. The next section overviews transforms, and discusses the desirable properties of transforms. Section 3 presents our indexing scheme. Our performance evaluation and optimization results are presented in section 4. The last section presents a summary and our conclusions.

2. Transforms

Overview of Transforms

Transforms are applied to signal (spatial signals like images) to transform the data to the frequency domain. Some of the most desirable properties of a good transform [4] are:

(1) energy compactness, which comes largely from decorrelating the original data;
(2) robustness to noise; and
(3) correspondence with the human auditory and visual system.

The last property means the audio/visual components to which the human senses are sensitive are mapped into certain recognizable frequency coefficients.

Interestingly, wavelet and DCT [2,3] have been found to possess all the above three properties. Specifically, they compact most of the energy into the low frequency coefficients, they map noise mainly to the high frequency coefficients, and the human eye and ear are most sensitive to the low frequency components. Therefore, a good indexing scheme uses a few low frequency coefficients to index image data. This is elaborated in the next section. It must be noted that other transforms, such as Haar and Hadamard, possess the above properties to a lesser degree and that the locations of the high energy coefficients in those transforms are not static but vary from signal to signal [6].

Wavelet

Wavelets [3,5] are increasingly used in the field of still image and video compression. Recent results have shown a significant advantage of this technology for still images over the more traditional DCT-based methods which are used in the JPEG industry standard [7]. Wavelet-based methods offer the advantage of a better trade-off between complexity, compression and quality.

Wavelets perform multirate signal filtering, decomposing the signal into a number of frequency subbands. The first subband is the low-frequency subband, while the other subbands are high-frequency subbands. The low-frequency subband usually contains the highest energy, while the high-frequency subbands usually contain comparatively less energy. A primary advantage of wavelets over classical transforms like FFT and DCT is that they are naturally multi-resolution and scaleable.

DCT

The discrete cosine transform (DCT) [2] has become a standard method of image compression. DCT offers a number of advantages. First of all, DCT has a high compression efficiency since it avoids the generation of spurious spectral components. Second, it corresponds fairly well with the human visual system (HVS). Typically in DCT the image is divided into 8x8-pixel blocks, which are each transformed into 64 DCT coefficients.

3. The proposed Indexing Scheme

Outline of Our Technique

We have developed an indexing scheme for image data based on transforms employed in signal processing and lossy data compression. The focal point of our indexing approach is to apply a suitable transform such as DCT, FFT, and Wavelet to the data, to produce a set of coefficients appropriate for indexing. The search scheme would be based on the selected number of coefficients and an appropriate matching criterion. Such a small number of coefficients reduces the index space and the search time. Our results show that certain wavelet transforms perform better than FFT or DCT.

The transform-based approach to indexing can be outlined as follows. The wavelet transform is applied to each image several times until the lowest-frequency subband becomes small enough. The number of times the transform is applied is a parameter to be optimized. That subband can then be transformed with DCT, and the first M low-frequency coefficients are taken as the index of the original image, where m is a relatively integer parameter to be determined.. When searching for (near) match to a query signal I, the same indexing scheme is applied to obtain an m-tuple index for I; afterwards, a similarity search for that index is performed on the databases of indices.

The Indexing Scheme

Applying the Wavelet transform on the given image results in isolating the low-frequency subband that represents the output of the low pass filter. This low-frequency subband contains all most of the components to which the HVS is most sensitive. Applying the wavelet transform recursively on the low-frequency subbands R times will reduce the size of the low-frequency subband. There is a tradeoff between the number of times the transform is applied, on the one hand, and the indexing capability of the resulting low-frequency subband. Optimizing this tradeoff is very critical.

Rather than reducing the size of the low-frequency subband to the desired size but risking its indexing suitability, we first obtain a medium-size low-frequency subband, and then apply the DCT transform on that subband. Afterwards, a small number M of the low-frequency DCT coefficients are taken to be the image index. The outline of the indexing scheme is illustrated by Figure 1.

The question now is the optimization of R, the number of times the wavelet transform is applied. We optimize R experimentally.

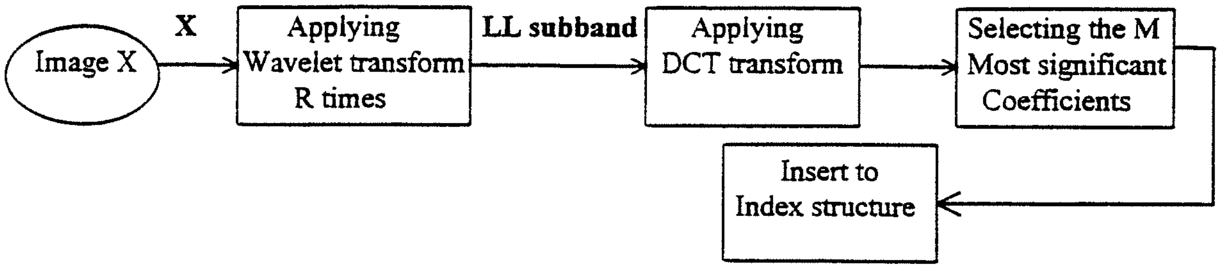

Figure1. Indexing scheme for image X

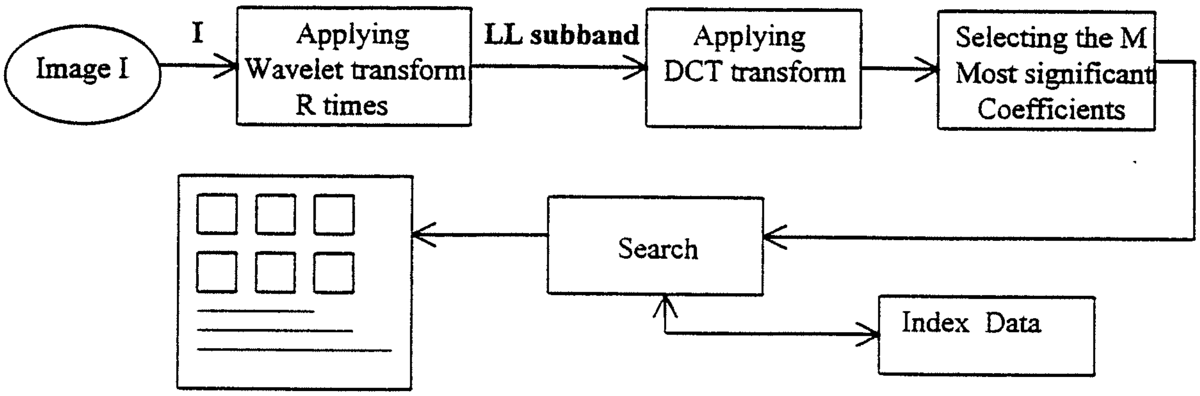

Figure 2. Searching scheme for image I

The Searching scheme.

When a query is presented in the form of an image I, the wavelet transform is applied with the same choice of wavelet used in the above index scheme, R times (the same number applied on the index), then the DCT transform is applied on the lowest-frequency subband. The first M low-frequency coefficients are taken to form the search sequence. Afterwards, a similarity search for that index is performed on the database of indices, using the mean-square error (MSE) as the similarity (or rather dissimilarity) measure. The outline of the searching scheme is illustrated by Figure 2.

The Choice of the Wavelet

The second author has conducted extensive studies on choosing the best wavelets for image compression [1]. He generated and evaluated over 4000 biorthogonal wavelets, and found that about two dozen wavelets give good performance, while most of the remaining wavelets give poor performance. In this paper, we use the best wavelet that was found in [1].

4. RESULTS

We have implemented our proposed indexing scheme, and optimized the choice of R. Note that when R=0, the indexing scheme reduces to an all DCT indexing. Therefore, we have the benefits of not only optimizing for R, but also comparing all-DCT indexing with wavelet-DCT indexing.

The performance metrics are the hit ratio and the search time. The hit ratio (HR) is the number of reported hits divided by the total number of actual matches. A related metric is the False Misses Ratio (FMR), which is the ratio of unreported matches to the total number of actual matches. Clearly, FMR=1-HR, and therefore, one needs to measure and maximize just the hit ratio. The False Hit Ratio (FHR)= F reported / H reported, where F reported is the number of reported but incorrect matches, and H reported is the total number of reported matches. The Search time is defined as the time between the submission of the query and the presentation of the results.

Our experimental results our shown in Figure 3, where the hit ratio is shown as function of the index size M, for different values of R. The plots clearly show that the wavelet-DCT indexing scheme is superior to all-DCT indexing, and that wavelet-DCT indexing is optimal for small values of R. The more Wavelet is applied on an image, the smaller is the hit ratio for the same number of coefficients.

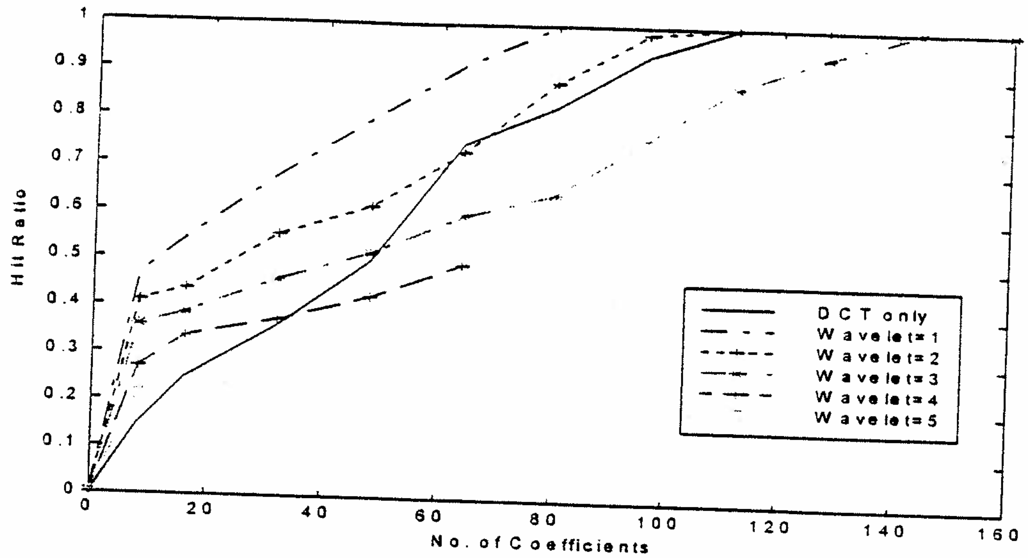

Figure 3. Hit ratio vs number of coefficients

However, there were no false misses in any of the search schemes. We must note, though, that the index search algorithms are expectedly more robust against noise. The larger query coefficient sizes result in better hit ratio but it increase the search times. It must be noted also that beyond a certain size, there is no remarkable improvement in the hit ratio.

5. CONCLUSION

In this paper, we proposed an indexing scheme for image data in multimedia databases based on transform techniques used in signal processing and data compression. The results have shown the effectiveness of transform coefficients as indices to image data, in terms of search hits and efficiency of searches.

We have implemented the indexing scheme, and conducted extensive evaluation to optimize (1) the choice of the wavelet, (2) the number of times the wavelet transform is applied, and (3) the number of DCT coefficients taken as index. Furthermore, we compared the performance of our indexing scheme with other schemes. Our results show that our scheme has significantly higher performance in terms of hit ratio, assuming the same index size. Our results also show that to derive the best performance out the wavelet-DCT hybrid indexing, the number of times the wavelet transform is applied on an image should be small.

We are considering variations and elaboration of our basic indexing scheme to further improve its performance. This and other indexing approaches will appear in our future work.

6. REFERENCES

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