Wavelet Based Compression for Image Retrieval Systems

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Abstract – In this paper, the investigation on using the ZTE /modified SPIHT wavelet based compression algorithm for the image retrieval system is presented. As ZTE/modified SPIHT algorithm codes an image into multi-layer bitstreams, the base layer and enhancement layer bitstreams, it provides superior benefits to the retrieval system compared to other compression methods. Since the base layer bitstream is analogous to a thumbnail image, it eliminates the redundancy of data. Moreover, the enhancement layer bitstream also allows fast transmission that enhances the performance of retrieval systems.

Keywords: Image retrieval systems, SPIHT, Wavelet based compression, ZTE

I. INTRODUCTION

An overwhelming accumulation (storage, transmission, processing etc.,) of digital images has tremendously increased in the past few years. The Internet is an example of a distributed database system that contains several millions of digital data. One difficulty for the Internet’s users is to search the information from the very large database both efficiently and effectively. Therefore, it is necessary to develop a tool (retrieval system) to help the user search in the database. Recently, number of researchers have been active in retrieval systems [1][2]. Most of them emphasize on developing the relevant algorithms for attribute descriptors. However, to develop a retrieval system, not only finding the efficient descriptors but also efficient ways to represent an image (retrieval database) are also needed. Therefore, in this paper, we introduce the new wavelet based coder, the ZTE (Zerotree Entropy)/modified SPIHT (Set Partitioning in Hierarchical Trees) algorithm, to compress images stored in retrieval database so that it provides the superior image quality at high compression ratios and also reduces the storage space by eliminating the redundancy of thumbnail and fine image.

In the next section, wavelet compression and its properties are addressed. Then the structure and details of the ZTE/modified SPIHT algorithm are described in section 3. The implementation of this algorithm in retrieval systems is explained in section 4. The performance of the proposed method and the results are discussed in section 5. Finally, we outline the benefits of the ZTE/modified coder to the retrieval system in section 6.

II. OVERVIEW OF THE WAVELET BASED COMPRESSION METHODS

The basic structure of baseline wavelet based coder is illustrated in Figure 1. This structure is the skeleton for all wavelet based algorithms. It consists of two parts, the encoder (Figure. la) and decoder (Figure. lb). The encoder consists of four processes: wavelet transform, quantization, encoder and entropy coding. The decoder has the inverse operations of encoder.

The baseline wavelet based compression (zonal coding) method was first proposed in [3]. Even though it outperforms the DCT based algorithms at high compression ratios (later has blockiness problem), the baseline wavelet based algorithm suffers from some defects, i.e. progressive transmission property. Note that the progressive transmission is one of the essential features in real applications (i.e., over Internet), such that it is needed to send the successive data packets that produce successively increased resolution of the received/reconstructed image. To overcome the lack of progressive transmission in baseline wavelet based algorithm, Shapiro [4] introduced the concept of Embedded Zerotree Wavelet (EZW) algorithm utilizing the embedding process called bit-plane coding. Further, the EZW algorithm is refined and has been superseded by the SPIHT algorithm [6]. By carefully organizing the spatial orientation trees in a manner that tends to keep insignificant coefficients together in larger subsets, the
SPIHT algorithm significantly improves the compression performance. Another disadvantage of the baseline wavelet based algorithm is that it is impossible to specify the exact compression rate in advance or exact PSNR to be achieved. Consequently, the Zero Tree Entropy (ZTE) algorithm which is developed based on the zonetree concept of EZW has been proposed in [5]. The ZTE algorithm employs the spatial orientation tree (SOT—EZW property) but rearranges the SOT structure to form a wavelet block (WB). This provides a good image quality with a constraint on fixed bit rate while sacrificing the progressive transmission. Recently, utilizing the benefits of both ZTE and SPIHT algorithms, the ZTE/modified SPIHT (also called HC-RIOT—Homogenous Connected-Region Interested Ordered Transmission) algorithm is proposed in [7]. This algorithm gains the good quality image at fixed bit rate from the ZTE algorithm and the progressive transmission from SPIHT algorithm. (see next section).

III. THE ZTE/MODIFIED SPIHT ALGORITHM

Initially, the ZTE/modified SPIHT algorithm has been introduced for the low bit rate transmission. It permits transmission over varying bandwidth networks by coding an image into two layer bitstreams (Figure 2.), the based layer and enhancement layer. First it transmits a very high compressed fixed rate bitstream (the base layer bitstream), which carries most significant information necessary for reconstructing the recognizable (coarse) image. In the base layer encoder, an image is decomposed using Daubechies 9/7 symmetric tap filter into four levels. The wavelet coefficients are then coded obtaining the base layer bitstream. The key development that is added to the base layer bitstream is the Wavelet Block Chain (WBC) [7]. The WBC identifies and labels homogenous block based regions of the image into edge, smooth or detail regions. It improves perceptual coding as the encoder factors this classification information into its rate distortion criteria. Also, the residual (less significant (unprocessed coefficients) information of the image) is progressively transmitted by using the refinement bitstream, the enhancement layer bitstream. Since the image quality depends on the amount of enhancement information, the networks that have higher bandwidth are able to receive the higher image quality.

In Fig. 3, the block diagram of the ZTE/modified SPIHT encoder is shown. It consists of six different processes: (1) 2D-DWT, (2) ADZ/UTQ (Adaptive Dead Zone/Uniform Threshold Quantization), (3) ZTE/WBC encoder, (4) LIR (a list of insignificant regions) formation process, (5) perceptual weighting, and (6) modified SPIHT encoder. The ZTE/WBC and Modified SPIHT encoder outputs the base layer and the enhancement layer bitstreams, respectively. The ZTE/WBC encoder is basically designed based on the concept of the ZTE algorithm. The modified SPIHT coder is the refined version of the SPIHT algorithm for coding the unprocessed coefficients by the ZTE/WBC encoder and thus providing the progressive transmission. The ZTE/modified SPIHT decoder (Figure. 4), is analogous to the encoding counterparts since the techniques developed consider both parts of the codec to operate at the same time.
IV. IMPLEMENTATION OF THE ZTE/MODIFIED SPIHT CODER IN IMAGE RETRIEVAL SYSTEMS

In this section, the investigation on using the ZTE/modified SPIHT algorithm in image retrieval systems is addressed. The retrieval system used in the proposed method consists of two main processing phases (see Figure 5), the attribute generation phase and the query phase. The former serves as a preprocessing operation for the image retrieval system. Its functions are to prepare, arrange, store and manage information in the database. The operations of this phase are segmentation, feature extraction and image compression. First, each image in the database is segmented into groups of regions (objects) of interest such that their content features such as shape, color, texture and spatial properties are individually extracted. For the simplicity of transmission and the beneficial saving in storage space, such an image is compressed into a compact form. In the proposed system, we utilize the ZTE/modified SPIHT as the compression method. The final operation of the attribute generation phase is to store both the compressed images and their attributes in the database. On the other hand, the query phase serves as the user interface. It consists of three processes, query generation, matching operation and content extraction. In this phase, a user picks up the query image from the available sample images (Query-by-Example). The selected query is segmented into meaningful regions, then the interested regions are analyzed and extracted to form apriori query attributes. These attributes are sent to the matching process to search for the possible outputs in the image database. Then, in matching process, the similarity between attributes of the query image and database images is measured. After matching operation, the images with maximum likelihood are retrieved and the thumbnail (low-resolution version) of all candidate images is delivered to the user’s terminal. Once user selects images from a candidate set, the fine image (high-resolution version) is transmitted to the end user.

Generally, two versions (thumbnail and the fine version) of the image are stored in database which results in preserving the redundancy of information. The ZTE/modified SPIHT coder compresses an image into two-layer bitstreams (the base and enhancement layers). The base layer can be considered as a thumbnail at a very high compression bitstream and it provides a very good quality of reconstructed (coarse) image. This small size bitstream allows fast browsing of retrieved candidate images by the user. Once the user makes a decision on the candidate images, only the enhancement bitstreams of such images are transmitted and combined with the earlier transmitted base layer bitstream providing fine images. Sending only enhancement layer bitstream enhances the transmission performance because we do not have to send the entire image.

V. RESULTS

To evaluate the performance of ZTE/modified SPIHT algorithm for compressing images in the retrieval database, public domain test images (Lena, Peppers, Jet etc.) of size 512x512 with 8 bpp are used. In the simulation, test images are lossy compressed at compression ratio of 10:1. The considerations used to evaluate the proposed method are the compression performance and the capability in saving space of the ZTE/modified SPIHT algorithm.

For the former evaluation, we compare the compression performance of the ZTE/modified SPIHT algorithm with those of two other well-known algorithms, the DCT based JPEG [8] and SPIHT algorithms. In Fig. 6, the compression performances of these three algorithms on Lena image are illustrated. The ZTE/modified SPIHT algorithm is comparable to that of SPIHT algorithm and outperforms the JPEG algorithm, especially at high compression ratios.

![Figure 6. Compression performances of SPIHT, JPEG and ZTE/modified SPIHT.](image-url)
Most of the retrieval systems use JPEG standard to compress and store the images in database. For the evaluation on the efficiency of the use of storage space, the proposed algorithm is compared with the JPEG standard. Assume that the size of image is 512x512, its corresponding thumbnail is 200x200, and compressed at compression ratio of 10:1. In Fig. 7, the storage spaces required for the compressed Lena (including both thumbnail and fine image) image at different PSNR are illustrated. The results show that for the same image quality (PSNR) of the fine image, the JPEG requires more storage space than the ZTE/modified SPIHT algorithm.

![Figure 7. Bit requirements of the retrieval database (Lena image).](image)

In Figure 8., the fidelity of the Lena image, compressed by both JPEG and the ZTE/modified SPIHT algorithms at compression ratio of 10:1, is shown. The image coded by the ZTE/modified algorithm, PSNR =37.09 dB (Fig. 8b) shows the comparable fidelity as that coded by JPEG, 36.86 dB (Fig. 8a). Moreover, the thumbnail image that is reconstructed from the base layer yields the fine quality image.

**VI. Conclusions**

In this paper, we propose an alternative image compression method, the ZTE/modified SPIHT wavelet based algorithm for image retrieval systems. The proposed algorithm provides not only an excellent high compression performance, but also fastens browsing/transferring of the retrieved images. Moreover, the base layer (with low fixed bit rate) of the ZTE/modified SPIHT coder provides a good quality recognizable image which can be used as thumbnail. The proposed methodology enhances the retrieval performance in three ways, (1) it eliminates the redundancy between thumbnail and fine image since the base layer of the ZTE/modified SPIHT algorithm can be used as the thumbnail, (2) it provides fast browsing of the candidate images since only base layer is transmitted (3) it allows fast transmission of the retrieved image (after making a decision) since only the enhancement layer is delivered to the end user. Further research on color image retrieval system is being done.

**VII. References**