AN ANALYSIS &IMPLEMENTATION OF COMPRESSION TECHNIQUES WITH JPEG CODED PHOTO ALBUMS

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Abstract -The explosion in digital photography poses a significant challenge when it comes to photo storage for both personal devices and the Internet. In this paper, we propose a novel lossless compression method to further reduce the storage size of a set of JPEG coded correlated images. In this method, we propose jointly removing the inter-image redundancy in the feature, spatial, and frequency domains. For each album, we first organize the images into a pseudo video by minimizing the global predictive cost in the feature domain. We then introduce a disparity compensation method to enhance the spatial correlation between images. Finally, the redundancy between the compensated signal and the corresponding target image is adaptively reduced in the frequency domain. Experimental results demonstrate the efficiency of our proposed lossless compression.

Keywords — DCT, Entropy Coding, Image compression, Image coding, JPEG Image set.

I.INTRODUCTION

The increasing number of digital photos on both personal devices and the Internet presents a significant challenge in terms of storage and bandwidth. The most popular way to reduce the size of a photo is JPEG compression. Though some digital cameras support raw data storage of captured photos, the majority of captured photos are compressed using image compression schemes, e.g. JPEG and JPEG2000. Though, individual compression ignores the redundancy between images when dealing with a set of correlated images. To reduce the inter-image redundancy between images, a number of image set compression schemes have been proposed. When a set of images are similar enough, a representative signal (RS) (e.g., an average image) can be generated from the images and the differential signals and the RS are coded For lossy compression, the images can also be organized into a pseudo video in which the prediction structure is determined via a MST (minimal spanning tree) and then coded like a video sequence using video coding, e.g. HEVC. Though efficient, all the schemes are presented to compress raw images rather than the JPEG coded ones. As most of the photos today are compressed and stored in JPEG Format, a lossless recompression scheme for JPEG coded photo albums is desirable to reduce storage costs.

In this paper, we propose the first lossless compression method to further compress a set of JPEG coded correlated images. Our proposed scheme ensures identical reconstruction of both image content and JPEG binaries which is required for applications such as data backup, cloud storage. For each JPEG coded album, we propose a hybrid algorithm to remove the inter-image redundancy in the feature, spatial, and frequency domains jointly. We introduce the feature-based measurement to determine the prediction structure so that we can well handle the variations in rotation, zooming, and illumination. The disparity between images is then compensated by global and local alignments in the spatial domain. The final compressed file is achieved by reducing the redundancy in the frequency domain. Experimental results demonstrate the advantage of our scheme in terms of achieving much higher coding efficiency and lossless representation of the JPEG coded files.

II. OVERVIEW OF OUR SCHEME

Lossless compression of JPEG coded images is a tough topic. There are two key problems here: how to model the correlation among images and how to compress the differential signal without loss so as to achieve a reduced file size with regard to the JPEG coded one.

Fig. 1 illustrates the basic idea of our lossless compression scheme. In this scheme, we compress JPEG coded photo albums by make use of the redundancy between images inside each album. At the encoder side, for each input photo album, we first determine the prediction structure with regards to the feature level similarity between each pair of images. Based on the prediction structure, we then reduce the disparity between adjacent images by joint global and local compensation.

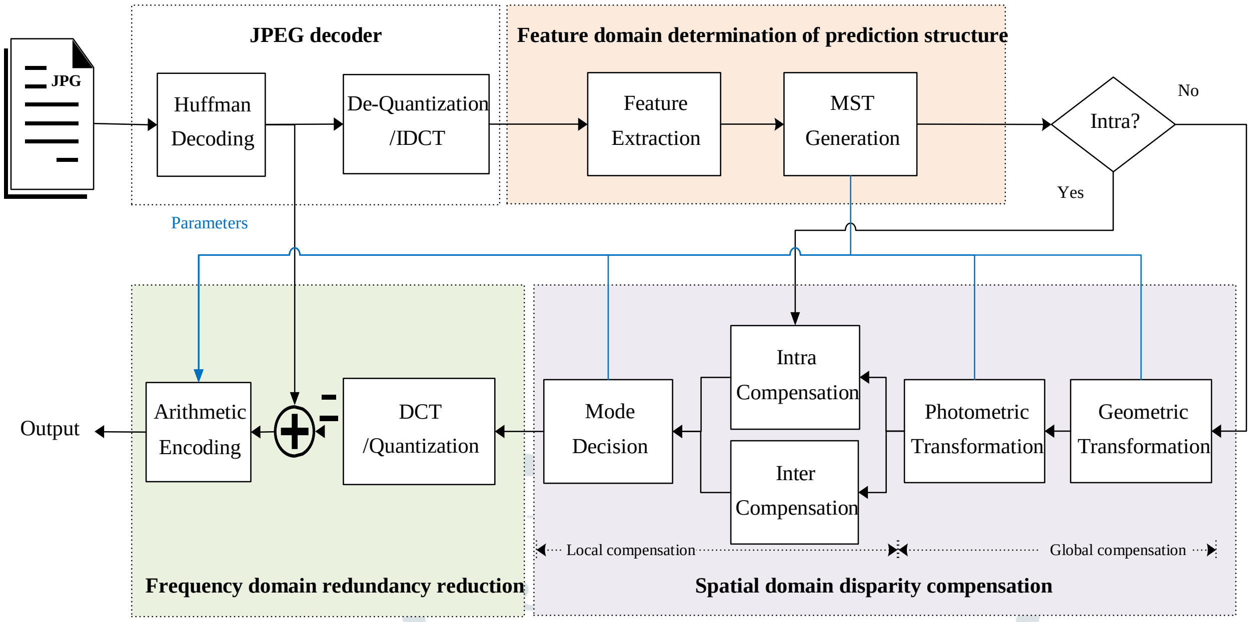


Fig. 1. Illumination of our proposed hybrid lossless compression scheme (encoding process).

The predictive difference between the compensated image and the target one is evaluated and compressed in the frequency domain. The generated frequency residues are coded via Entropy coding method used in JPEG to produce the coded album.

The corresponding decoding process is illustrated in Fig. 2. The prediction order is first decoded from the coded bit stream. Each predictively compressed (i.e. inter-coded) images can be decompressed individually like JPEG coded images. In the following section, the three modules in our hybrid lossless compression (as shown in Fig. 1), feature-domain determination of prediction structure, spatial-domain disparity compensation, and frequency-domain redundancy reduction, will be introduction detail.

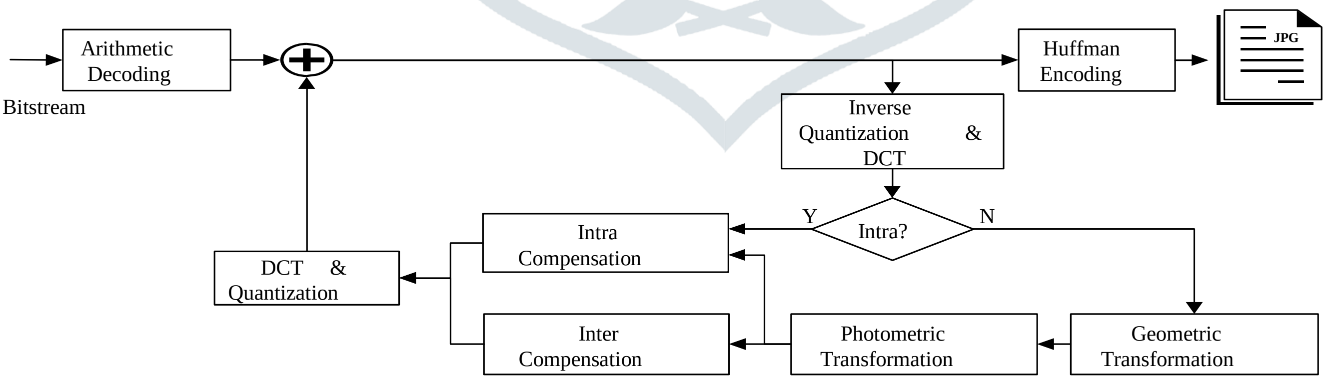


Fig. 2. Illumination of the decoding process of our proposed hybrid lossless compression scheme.

III.FEATURE DOMAIN DETERMINATION OF PREDICTION STRUCTURE

In contrast to natural video sequences, which have an inherent temporal correlation, images in an album have disordered and loose correlations. Moreover, the inter-image disparity in photo albums are more complicated than that in natural videos, as the images may vary a great deal in rotation, zoom, and illumination. The traditional pixel-level disparity measures, e.g. MSE, are not capable enough to deal with photo albums. In our proposed scheme, we measure the similarity between images by the distance of their SIFT descriptors to avoid the impact of large motion offsets and luminance changes. A SIFT descriptor describes the distinctive invariant feature of a local image region, which consists of a location, scale, orientation, and feature vector. The key-point location and scale are determined by finding the maxima and minima of difference of Gaussian signals. The feature vector is a 128-dimensional vector, which characterizes the local region by the histogram of gradient directions, and the orientation denotes the dominant direction of the gradient histogram. SIFT descriptors have been demonstrated to have a high level of distinctiveness and thus widely used in image search and object recognition.

We approximate the predictive cost between images by the distance of their SIFT descriptors. Taking two images, I_n and I_m, as an example, the predictive cost $p_{n,m}$, using I_n to predict I_m, is determined by the average distance of the set of matched SIFT descriptors $S_{n,m}$ between these two images.

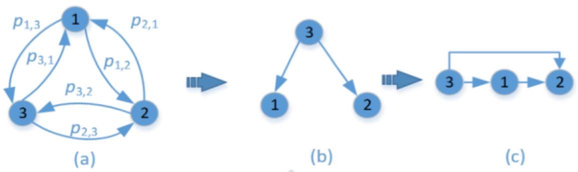


Fig. 3. MST-based determination of prediction structure.

$$p_{(n,m)} = \frac{1}{|S_{n,m}|} \sum_{\forall (s_n^r, s_m^r) \in S_{n,m}} D(s_n^r, s_m^r) \quad (1)$$

Where s_n^r and s_m^r are SIFT descriptors detected from I_n and I_m, respectively, (s_n^r , s_m^r) denotes the r^{th} pair of matched SIFT descriptors in the set $S_{n,m}$, and |A| is the number of elements in a set A. The distance between two descriptors is calculated as

$$D(s_n^r, s_m^r) = \frac{1}{v_m^r} ||\mathbf{v}_n^r - \mathbf{v}_m^r||^2 \quad (2)$$

Where $v^r{}_n$ and $v^r{}_m$ denote the 128-dimentional feature vectors of s_n^r and s_m^r , respectively.

Let II = I_1 ,I_2,...,I_N denote an image set that contains N correlated images. We estimate the predictive cost between each pair of images using 1 and generate the directed graph, as exemplified in Fig. 3 (a). Then an MST can be deduced from the directed graph by minimizing the total predictive cost [10], as shown in Fig. 3 (b). The prediction structure of the images in I is determined accordingly by depth-first traversing the MST, as denoted in Fig. 3 (c). The depth can be limited to one when random access of a single image is required.

IV. SPATIAL-DOMAIN DISPARITY COMPENSATION

Given the prediction structure of an image set II, we can reorganize the images into a pseudo video and directly use motion compensation and estimation technologies for video coding to reduce the disparity between references and target images. However, as mentioned before, the disparity in an image set can be more complicated than that in a video sequence. To solve this problem, we adopt the prediction method to exploit the correlation between images.

V.FREQUENCY-DOMAIN REDUNDANCY REDUCTION

After the disparity compensation, the redundancy between the target and compensated blocks will be reduced by calculating the residual signal. In all previous image set compression schemes, the residual signal is generated in the spatial domain. However, since the quantization step is skipped in the lossless compression, residues generated in the spatial domain usually lead to a heavily-tailed distribution and consequently make the following entropy coding less efficient in comparison with the lossy coded coefficients of the JPEG-coded image On the other hand, JPEG coded images are quantized during lossy compression. It enables us to introduce the quantization in the frequency-domain redundancy reduction . In our scheme, we generate the residual signal between quantized

DCT coefficients of the target and compensated blocks. As shown in Fig. 1, the quantized DCT coefficients of the target JPEG coded image can be acquired by the JPEG entropy decoding.

We then perform the same 8×8 DCT transform as well as the quantization of the JPEG coded image on the corresponding compensated block. The residual signal is generated by calculating the difference between the two sets of quantized DCT coefficients. The one generated in the frequency domain is significantly light tailed and thus greatly helps enhance the efficiency of the subsequent entropy coding.

Though the quantization module is introduced, we ensure lossless recovery of the original JPEG coded images as the quantization is performed on the compensated signal instead of the residual one. All the prediction steps for lossless compression of the JPEG coded images as shown in Fig. 3 are invertible.

VI.ENTROPY CODING

In our scheme, the residual signal of each block is coded by the arithmetic encoder. Rather than directly utilizing an existing entropy coding method, we design new context adaptive statistical models with regard to the statistical distribution of the quantized DCT residues, since the distribution of the quantized DCT residues are different from those of signals generated in lossless or lossy image coding.

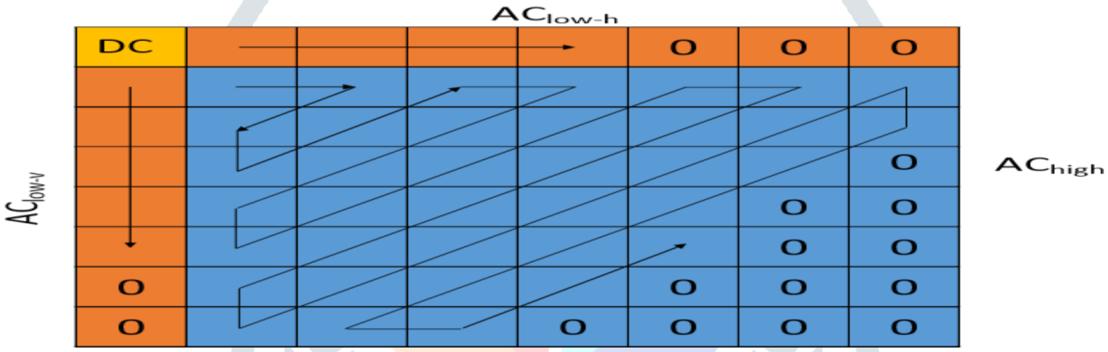


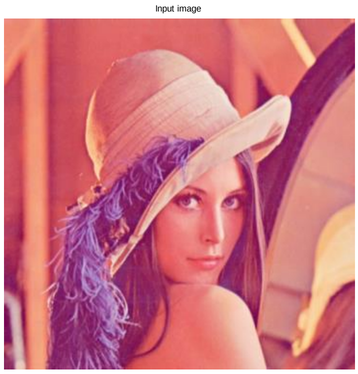
Fig. 4.Four partitions of an 8×8 DCT block.

VII. EXPERIMENTAL RESULTS

In this section, we evaluate the performance of our hybrid lossless compression scheme for JPEG coded images.

A) Simulation- The algorithm has been implemented using Matlab 2014a. A test image is taken to justify the effectiveness of the algorithm. **Fig. 5** shows a test image and resulting compressed images using JPEG and the proposed compression methods.

(a) (b)



(c)

Fig.5 (a) Input image of 190 kb (b) Compressed image of 30kb (c) Reconstructed input image.

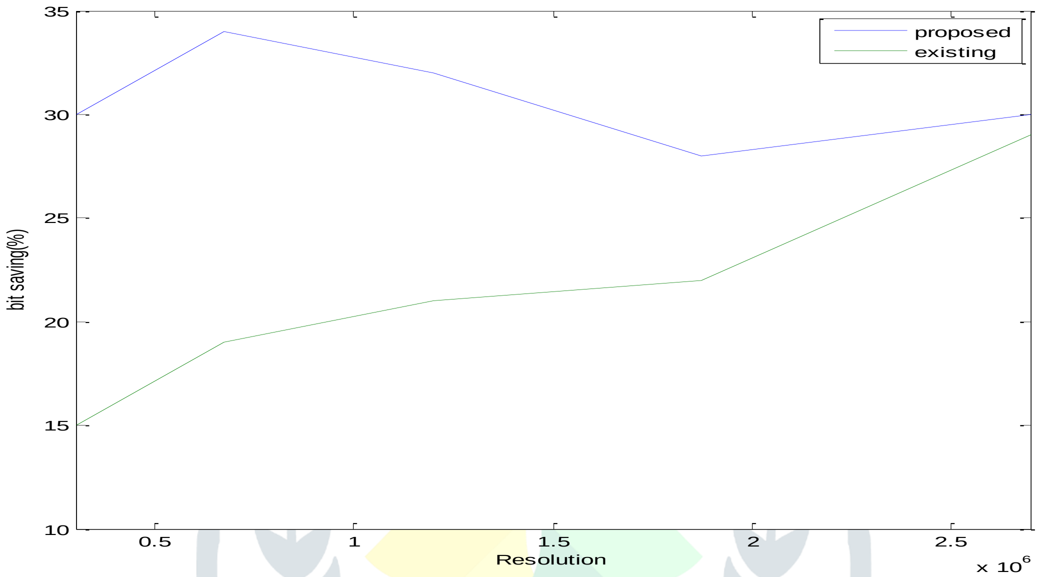


Fig.6 Bit saving graph for input image.

VIII. Conclusion

In this paper, we proposed a new hybrid compression method to further reduce the file size of JPEG coded image collections without any fidelity loss. In our proposed method, we determine the prediction structure of each image collection by a feature domain distance measure. The disparity between images is then reduced by joint global and local compensations in the spatial domain. In the frequency domain, the redundancy between the compensated and target images is reduced and the remaining weak intra correlations are further exploited in our entropy coding. In this paper, we have proposed the first lossless compression scheme for reducing the file size of JPEG coded photo albums. We propose a novel hybrid scheme to efficiently make use of the correlation between images in feature, spatial, and frequency domains, respectively. . From the experimental results it is evident that, the proposed compression technique gives better performance compared to other traditional techniques.

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