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GJCST-F Classification: I.4.2

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I. Introduction

The rapid growth of digital imaging technology in conjunction with the ever-expanding array of access technologies has lead to a new set of requirements for image compression algorithms. Not only are high quality reconstructed images required at medium-low bitrates, but as the bitrate decreases, the quality of the reconstructed image should degrade gracefully. The traditional multi-bitstream solution to the issue of widely varying user resources is both inefficient and rapidly becoming impractical. The bitlevel scalable codecs developed for this dissertation allow optimum reconstruction of an image from an arbitrary truncation point within a single bitstream. That is, the encoder is effectively isolated from the decoder and the target decode rate need not be known at encode time. The discrete wavelet transform is utilized to provide a multi-resolution decomposition of an image. A wavelet coefficient's magnitude is then directly proportional to the fidelity of the reconstructed image. To exploit this in a scalable manner, a progressive bitplane transmission scheme is utilized. Each bitplane is represented by means of a significance map. It is the efficiency of representation of the significance map that this dissertation explores.An important characteristic underlying the design of image processing systems is the significant level of testing and experimentation that normally is required before arriving at an acceptable solution. This characteristic implies that the ability to formulate approaches and quickly Prototype candidate solutions generally plays a major role in reducing the cost and time required to arrive at available system implementation.

An image may be defined as a two-dimensional function, $f(x, y)$, where x and y are spatial coordinates, and the amplitude of f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point. When x, y, and the amplitude values of f are all finite, discrete quantities, we call the image a digital image. The field of digital image processing refers to processing digital images by means of a digital computer. A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels. Pixel is the term most widely used to denote the elements of a digital image Vision is the most advanced of our sense, so it is not surprising that images play the single most important role in human perception. However, unlike humans, who are limited to the visual band of the electromagnetic (EM) spectrum, imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves. They can operate also on images generated by sources that humans are not accustomed to associating with images. These include ultrasound, electron microscopy, and computer-generated images. Thus digital image processing encompasses a wide and varied field of applications.

Digital imagery has had an enormous impact on industrial, scientific and computer applications. It is no surprise that image coding has been a subject of great commercial interest in today's world. Uncompressed

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digital images require considerable storage capacity and transmission bandwidth. Efficient image compression solutions are becoming more critical with the recent growth of data intensive, multimedia-based web applications.

II. Image Coding Algorithm

In the previous two chapters it has been established that the building blocks required to achieve the stated research targets include the discreet wavelet transform, bitplane progressive scalar quantization and adaptive arithmetic entropy coding. Each bitplane is represented by means of a significance map. It is the efficiency of representation of this map that determines the compression performance. Sets composing the significance maps can be classified as "Tree", "Block" or "Hybrid" based. This chapter reviews the most influential literature in each classification that has helped shape the current state-of-the-art of bitplane progressive image compression

Efficient image compression solutions Image Coding Algorithm : In the section and previous it has been established that the building blocks required to achieve the stated research targets include the discreet wavelet transform, bitplane progressive scalar quantization and adaptive arithmetic entropy coding. Each bitplane is represented by means of a significance map. It is the efficiency of representation of this map that determines the compression performance. Sets composing the significance maps can be classified as "Tree", "Block" or "Hybrid" based. This chapter reviews the most influential literature in each classification that has helped shape the current state-of-the-art of bitplane progressive image compression The algorithm maintains three lists: LIP List of Insignificant Pixels.LSP List of Significant Pixels.LIS List of Insignificant Sets.The LIP and LSP contain nodes (2D matrix coordinates) of single coefficients, while the LIS contains nodes that are the roots of spatial orientation trees. The Offspring set, O (i, j), contains the direct offspring of the node at coordinates (i, j), that is the four coefficients at the same spatial location in the next level of the pyramid. Except at the highest and lowest pyramid levels, the offspring set is defined as:O(i, j) = {(2i, 2j), (2i, 2j + 1), (2i + 1, 2j), (2i + 1, 2j + 1)} (3.1)Nodes at the lowest level have no offspring and nodes at the highest level are grouped into 2x2 blocks whereby the upper left coefficient has no offspring. Figure 3.3 shows the parent-offspring relationship and the set definitions for a three level decomposition. It is essentially the same as EZW except in the way that the offspring of trees in the root subband are defined. The algorithm consists of four stages, the last three of which are repeated; initialization, sorting pass, refinement pass and quantization step update. The algorithm is initialized by adding all coe ficients in the lowest frequency subband to the LIP, and all those with offspring. EBCOT. The EBCOT algorithm introduces a number of new developments to the wavelet bitplane coding family. Compression to a specific rate is achieved as a two-tier process. The image is first compressed using a coding engine which does not consider the target bitrate, the second tier post processes the bitstream to produce a rate-distortion optimized bitstream for a specific rate. In EBCOT, each subband is partitioned into relatively small blocks of samples, called code-blocks. Each code-block is coded independently to produce an embedded bitstream for that block. Truncation points are marked in the embedded bitstream for each block and its contributions to overall distortion reduction is noted. The tier two algorithms select various truncation points from each block to construct the optimum bitstream for a given bitrate. The downside of the scheme is that for each desired embedded rate, truncation points have to be marked in each code block. EBCOT can approximate a true embedded scheme by selecting a large number, e.g. 50, truncation points for each code-block but the overhead associated with signaling the location and contributions from each truncation point has a negative effect on performance. EBCOT is essentially a bitplane coder. Code-blocks that contain significance relative to the current threshold are identified using a conventional quadtree coding approach. The size of the code-block is decided at compile time but is typically 16 × 16. Thereafter, individual coefficients in a code-block are identified as significant/ insignificant using a combination of coding primitives and context models. A context is chosen for each coefficient considering eight neighbors. Both sign bits and refinement bits are also arithmetically coded. Fractional bitplane coding is achieved using four passes for each bitplane. This increases computation but if the target bit rate is reached mid bitplane the advantage of fractional bitplane coding is that a better performance is achieved. Image compression systems are composed of two distinct structural blocks: an encoder and a decoder. Image $f(x, y)$ is fed into the encoder, which creates a set of symbols from the input data and uses them to represent the image. If we let n_1 and n_2 denote the number of information carrying units (usually bits) in the original and encoded images, respectively, the compression that is achieved can be quantified numerically via the compression ratio

III. Embedded Coding

The performance of an embedded image coding system significantly relies upon the efficiency of the entropy coder used for compression of bitplane data. The various bitplane compression algorithms in the literature can be loosely categorized into two classes: hierarchical set-partitioning coding and context-dependent sequential bitplane coding.

The hierarchical set partitioning is block *entropy coding* scheme .The energy clustering nature of subband coefficients is exploited by joint coding of bitplane data in blocks. With large numbers of samples tested and coded in groups, this class of coders has excellent speed and compression performance. Nevertheless, ever since publication of the benchmark work SPIHT by Said and Pearlman, we have not seen any significant and consistent advancement of this technique in *compression* presented in the literature, to author's knowledge, despite numerous research attempts. The context-based sequential bitplane coding is a *conditional entropy coding* scheme. The strong statistical dependencies of subband coefficients are effectively captured by the modeling contexts. With the elaborate high-order modeling scheme, the wavelet bitplane coder proposed by Wu reports the significant PSNR improvement over the best existing set-partitioning coders in the literature. Nevertheless, unlike the set-partitioning coder, the sequential bitplane coder processes and encodes the individual bitplane data sample by sample. Every pixel typically has to be visited at least once to finish a full bitplane coding pass, hence with an implied higher computational cost. Given the distinctive features of the two embedded coding schemes, it is certainly desirable to have an image coding system which combines these two powerful techniques and takes advantage of their respective strength at the same time. The proposed EZBC algorithm was developed to answer this challenge. It also adopts the set partitioning approach in the bitplane coding framework. However, instead of the classical zerotree coding scheme, it utilizes the more recent zeroblock coding scheme for hierarchical coding of wavelet coefficients. The development of EZBC is motivated by the experimental observation that strong dependency exists not only among subbands coefficients but also among quadtree nodes from quadtree representations of the subbands. Fig. 3.1 displays the *MSB maps* (indicating the bit indexes of the MSB's of individual quadtree nodes) of the quadtrees built up from the individual subbands of the decomposed Lena image. Each quadtree node $Q(i, j)$ is a basic *zero set* for grouping of *insignificant coefficients* and contains all coefficients from a block region as members. The value of the quadtree node is defined to be the maximal magnitude of its members. Interestingly enough, another pyramidal image description is thus provided by the individual quadtree levels, as shown in Fig. 3.1, in addition to the original subband pyramid generated by the wavelet transform. Self-similarity is clearly exhibited in such a multiresolution data representation across both resolution and quadtree levels. The image features, e.g., edges and contours can be easily identified in different hierarchies of the wavelet transform domain. The proposed EZBC algorithm is the first attempt to explore such rich dependency existent in quadtree representation of a decomposed image. With special care given to the design of the context modeling strategy, it is demonstrated in our experimental results that the compression performance of the set partitioning coder can be substantially improved. As it will become clear, EZBC can be thought of as a hybrid coding algorithm which aims at attaining the theoretical bound of coding bitrate (entropy rate) by joining block entropy coding and conditional entropy coding approaches.

The development of the EZBC image coding system is built upon several prior research works in the field of embedded wavelet image coding. The following advanced coding techniques are efficiently combined in the EZBC coding system: quadtree-based set partitioning for compact and flexible data representation,• context modeling for exploitation of statistical dependency between subband coefficients • bitplane de-interleaving to improve rate-distortion (R-D) performance, and context-dependent de-quantization to further utilize the source statistics accumulated during the bitplane decoding phase. Although many algorithms in the literature also attempted to join some of these coding tools, they either substantially increased the implementation complexity or just made limited improvement. For example, most set partitioning coders, also employ context-based arithmetic coding to further compression efficiency. However, the simple context modeling schemes utilized in these former algorithms are insufficient to accurately predict the status of a given quadtree node. The bitplane de-interleaving utilized in the conventional sequential bitplane coders is effective in improving the R-D efficiency of the embedded codestream. However, such improvement is accomplished at a cost of additional bitplane scans/passes. In EBCOT proposed by Taubman, the quadtree decomposition, run-length coding and conventional context-based bitplane coding work together for significance coding of subband coefficient. The quadtree decomposition therein only proceeds up to a pre-selected minimum sub-block size, 16×16 by default. The quadtree

IV. Codestreab Embedding

In order to have efficiently embedded codestreams, it is essential that the code data in the compressed file are ordered according to their relative efficiencies for distortion reduction. This basic concept is commonly called embedding principle. In the proposed algorithm, a fixed path for encoding of wavelet coefficient bitplane data is chosen as follows: The coding process advances in a bitplane-wise fashion from the most significant bit toward the least. In a given bitplane, the arrays of LINs are processed in an increasing order of quadtree level, as suggested by Islam and Pearlman in SPECK. That is, all the *pixels* in LIN[0] are processed first and all the *nodes* in LIN[1] are then processed next, followed by the processings of LIN[2], LIN[3], and so on. In this way, the busy areas in the transformed image are updated earlier via a few quadtree splitting and coding steps, resulting in a good rate-distortion performance. The refinement of the previous significant coefficients from LSP is executed at last. In a significance test pass of a given quadtree level or a coefficient refinement pass, the subbands are visited from coarse to high resolution (as indicated in

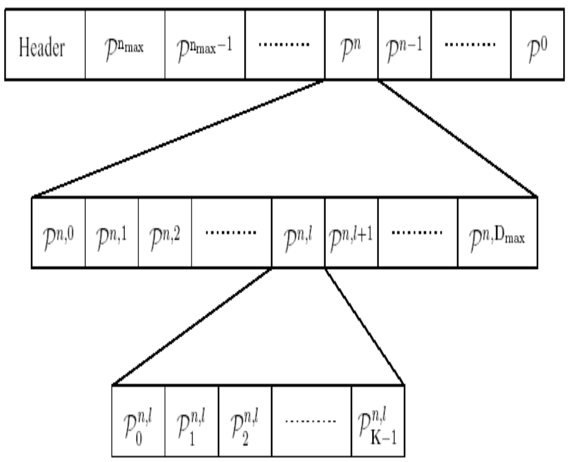

Figure 4.1 : Illustration of the hierarchical layout of a EZBC codestream

A hierarchical layout of a EZBC codestream is depicted in Fig. 4.1, where p^n denotes the bitplane pass n, $p_k^{n,l}$ the sub-bitplane pass for processing the insignificant nodes in $LIN_k[l]$ (routine CodeLIN(k, l)), and $p_k^{n,D_{max}}$ the sub-bitplane pass for the refinement of the significant coefficients in LSP_k (routine CodeLSP(k)). Similar to the bitplane de-interleaving scheme widely adopted in the sequential bitplane coders, EZBC effectively partitions each bitplane into multiple sub-bitplane passes $\{p_k^{n,l}\}_{n,l,k}$ for providing an embedded codestream of fine granularity. However, unlike the multi-pass approach proposed in, EZBC does not need to scan the individual pixels more than once in each bitplane pass because all the involved pixels for the individual sub-pass were already organized in separate lists. Although our pre-defined data embedding order is not optimized for the best R-D performance (as compared to the algorithms), our empirical data show the resulting relative performance loss is mostly insignificant. The effectiveness of the proposed data embedding strategy is further evidenced by the smooth R-D curves shown in our actual coding simulation results. It is worth mentioning that each bitplane pass could have been divided into even more sub-bitplane passes in our data embedding scheme to further improve the R-D performance of the resulting codestream. It is simply accomplished by partitioning of the existing lists into smaller sub-lists and then processing each sub-lists via separate sub-bitplane coding passes. The resulting computational and storage costs are still the same because the total number of the nodes to be stored and processed in all the maintained lists is unchanged. For example, our empirical data show that the refinement of the significant coefficients from the previous bitplane coding pass reduces distortion more efficiently than the refinement of the significant coefficients from the other earlier bitplane coding passes (if exist). The PSNR performance can thus be slightly improved by partitioning the existing refinement pass into multiple sub-passes, each for the refinement of the significant coefficients from particular bitplane level(s). Nevertheless, it is observed that the granularity of the resulting codestream by the current algorithm is already fine enough in practical image coding applications.

V. Result Analysis Observation

Original Image

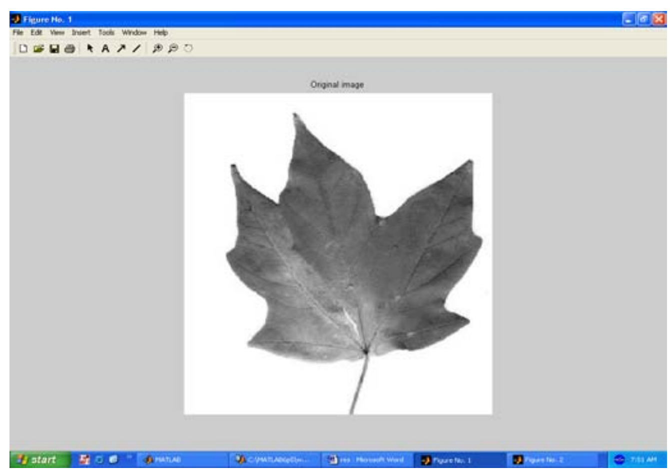

Figure 5.1 : Original leaf image sample

Recovered Image

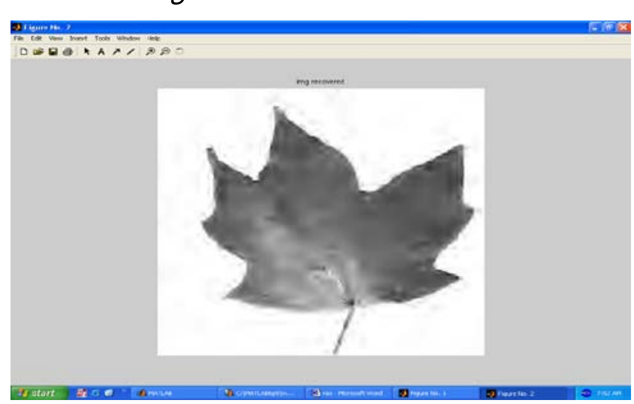

Figure 5.2 : Recovered image at 0.1 bpp

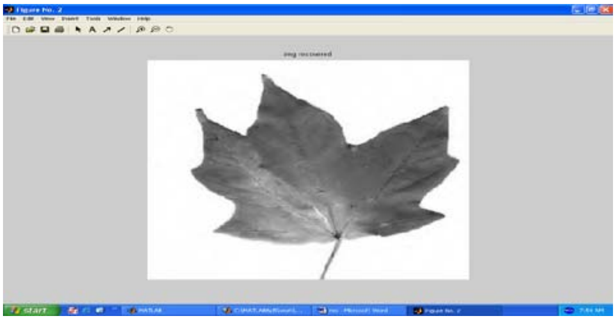

Figure 5.3 : Recovered image at 0.5 bpp

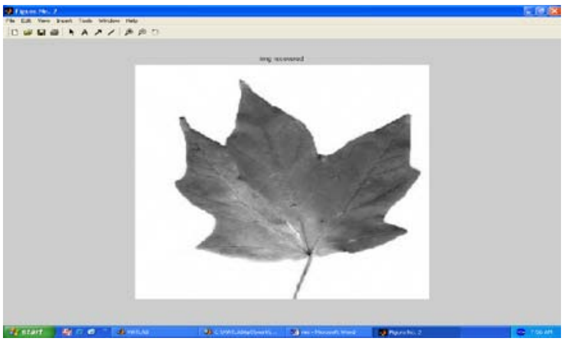

Figure 5.4 : Recovered image at 0.9 bpp

Bpp-PSNR plot

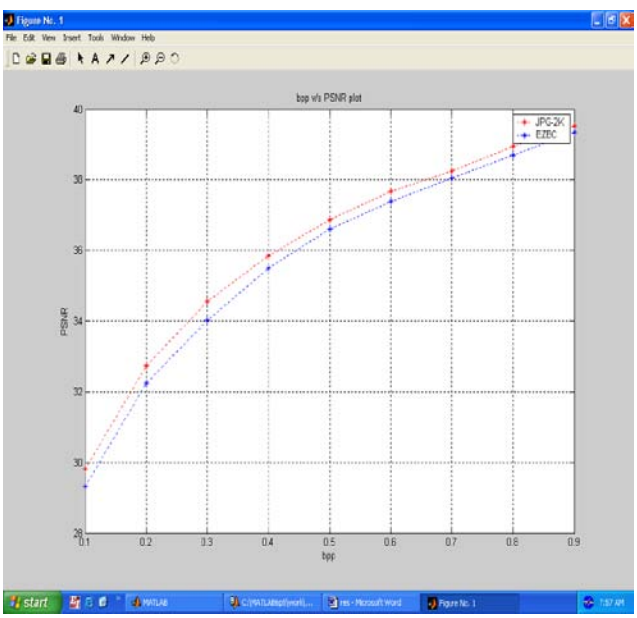

Figure 5.5 : PSNR v/s bpp plot for the given leaf imageSample-2

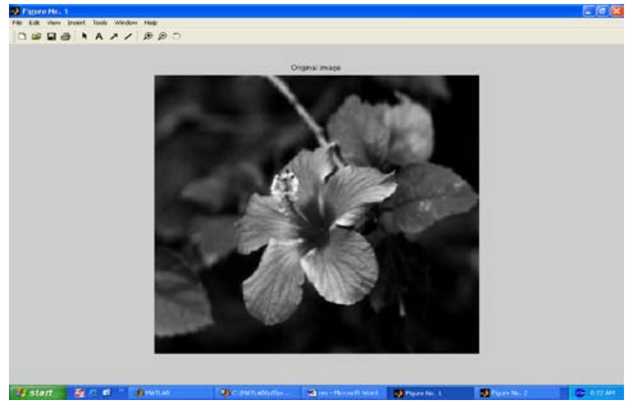

Figure 5.6 : Original flower image sample

Recovered Samples

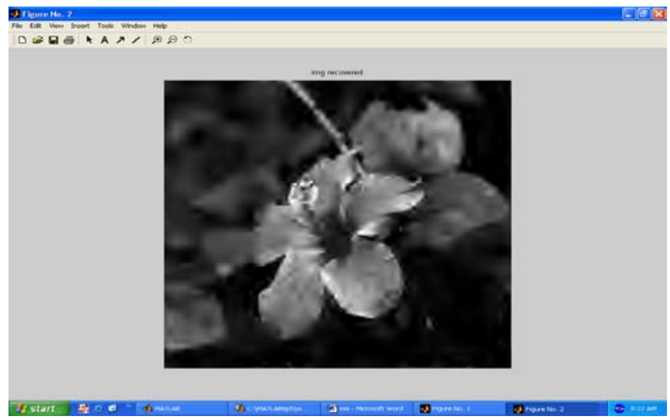

Figure 5.7 : Recovered flower image ample at 0.1 bpp

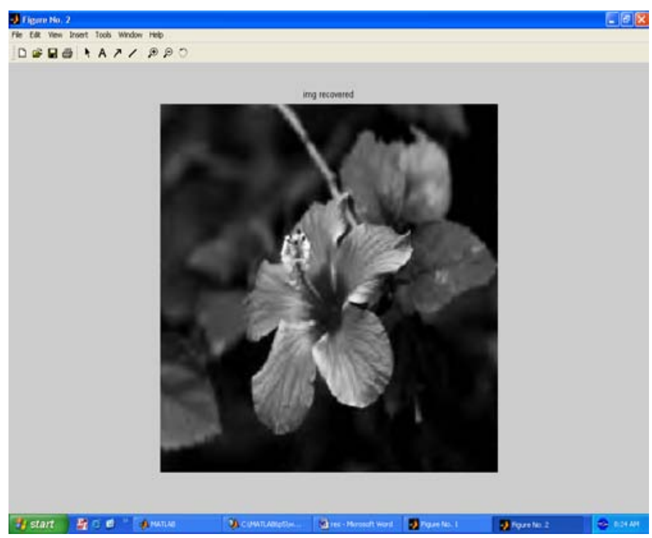

Figure 5.8 : Recovered flower image sample at 0.5 bpp

VI. Future Scope

This paper implements the coding algorithm on less noisy images. The work can be further extending for different kind of images having different properties. The project realizes EZW coding algorithm that can be further applied for image coding systems where embedded coding is used.techniques—set partitioning and context modeling—for efficient entropy coding of coefficient bitplane symbols. Unlike traditional zerotree-based set partition coders, we utilized the emerging quadtree-based zeroblock-coding scheme for hierarchical set-partition coding of wavelet coefficients. Exploitation of the strong statistical dependency in quadtree representation of the decomposed image is attempted in this work. Our coder has some attractive features of the traditional embedded bitplane coders such as precise rate control and multi -rate/-precision decoding. Without a zerotree spanning across different resolutions, this algorithm is ideal for resolution scalable coding. A substantial PSNR improvement over the state-of-the art algorithms in the literature is exhibited in extensive simulation results. A new algorithm for reconstruction of decoded wavelet coefficients. This technique features a context-dependent de-quantization strategy utilizing probability models dynamically accumulated in the decoding phase. Although the related PSNR improvement is not significant, it yields visually more pleasing coding results, as experimentally demonstrated the proposed-quantization algorithm is quite general and is expected to able to applied in other context-based wavelet bitplane coders, e.g., EBCOT, and ECECOW.

A reversible image coding system derived from the classical EZBC algorithm. The proposed coder exhibits excellent compression performance for both lossy and lossless image coding, as compared to competing a highly scalable and perceptually tuned image coding system was presented in related chapter, built upon the EZBC framework. Special care is given to modeling and coding of subbands so that the information related to desired resolution and precision levels can be efficiently retrieved from a single compressed .le. A variety of code stream formats can be easily composed from the hierarchically structured bit streams. As such, the encoding and decoding stages is allowed be effectively decoupled. Perceptual image coding is jointly addressed in a scalable coding system in this work. Unlike former research approaches adopted in the literature, the decoder or the stream parser exclusively performs “perceptual tuning” at the decoding/transmission times. Significant PSNR and visual improvements by the proposed scheme are presented in experimental results. A new embedded image coding algorithm EZBC using zeroblock coding of the subband/wavelet coefficients and context modeling was presented. With effective exploitation of context information at the individual levels of the quadtree representation of subband/wavelet coefficients, EZBC outperformed the well-known zerotree coder SPIHT and a more recent zeroblock coder SPECK in compression efficiency.

Our experimental results also indicate that the PSNR performance of the proposed algorithm is comparable to that of the JPEG 2000 test coder, a state-of-art image coder using context modeling and also a hybrid of pixel- and block- wise zero coding schemes. Nevertheless, EZBC adopts unified zeroblock coding framework and thus possesses the desirable low-complexity feature of this class of coders.

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