IMAGE COMPRESSION ON HIERARCHICAL DECOMPOSITION AND PIXEL PREDICTION

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ABSTRACT

This paper presents lossless color image compression algorithm based on the proposed method , "Hierarchical decomposition and pixel prediction". An input RGB color image is transformed into YCuCv color space by an Reversible Color Transform (RCT) . The luminance channel is encoded by any of the lossless image compression such as Context Based Adaptive Lossless Image Codec (CALIC) , JPEG-LS, or JPEG 2000 lossless. The chrominance channel Cu and Cv are encoded using hierarchical decomposition & pixel prediction. Arithmetic coder is used to encode the prediction error. For several set of test images, this algorithm is shown that the proposed method is better than JPEG2000 and JPEG-XR.

Keywords : *Lossless color image compression;reversible color transform;hierarchical prediction;context adaptive arithmetic coding;color transform coding;*

I. INTRODUCTION

Application of data compression are primarily in transmission and storage of information. Image data compression is concerned with minimizing the number of bits required to represent an image. Image transmission applications are in broadcast television, remote sensing, radar and sonar and teleconferencing and so on. As cameras and display systems are going high quality and as the cost of memory is lowered. Hence efficient lossless compression has become more and more important.

Lossless image Compression Algorithm :

The most widely used compression algorithms are JPEG,JPEG2000,JPEG-LS, jPEG-XR,LOCO-I and CALIC.

Loco-:I : Loco-:I

(LOw COmplexity Lossless Compression for Images) is a product of ISO/ITU standard for lossless and near-lossless compression of continuous-tone images, JPEG-LS[1][2]. It is based on a simple context model, which approaches the means of the more complex worldwide techniques for getting high-order dependency. The model is shaped for better performance in combination with an extensive relations of Golomb-type codes, which are adaptively selected, and an embedded alphabet extension for coding of low-entropy images.LOCO-I gains compression ratios similar to those obtained with state-of-the-art schemes based on arithmetic coding. It is within a few percentage points of the best available compression ratios, at a much lower complexity level .

Calic :

Context-based, adaptive, lossless image codec (CALIC). The codec obtain higher lossless compression of continuous-tone images.This high coding competence is

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gifted with relatively low time and space complexities. A elite feature of CALIC is the use of a large number of modeling contexts (states) to situation a nonlinear predictor and get a feel for the predictor to varying source statistics. The nonlinear predictor can approved itself via an error feedback mechanism by learning from its mistakes under a past contexts.. In this learning process, CALIC estimates only the hope of prediction errors conditioned on a large number of different contexts rather than estimating a large number of conditional error probabilities.

CALIC [3] was developed by ISO/IEC JTC 1/SC 29/WG 1 (JPEG) for lossless compression of continuous tone images.CALIC had the lowest lossless bit rates in six of seven image classes: medical, aerial, prepress, scanned, video, and compound document, and the third lowest bit rate in the class of computer-generated images.

Jpeg & Jpeg 2000 :

(Joint Photographic Experts Group-1992) is an algorithm designed to compress images with 24 bits deepness or grayscale images [4]. It is a lossy compression algorithm. One of the characteristics that make the algorithm very flexible is that the compression rate can be familiar. With a lesser compression rate to get a best quality, but the size of the resultant image will be bigger. This compression consists in making the coefficients in the quantization matrix larger when need more compression, and smaller when desire less compression. The algorithm is based on two visual effects of the human visual system. First, humans are more aware to the luminance than to the chrominance. Second, humans are more aware to changes in uniform areas, than in areas where there is more variation (higher frequencies).

JPEG- 2000 - is a wavelet-based image compression standard. It has higher compression ratios than JPEG. It usually makes the image more blurred than JPEG.

II . Encoding

a) Adaptive Arithmetic Coder

Arithmetic coding [5] yields better compression because it encodes a message as a whole new symbol instead of separate symbols. When a new symbol is coded, the precision required to present the range grows. Context-Based Adaptive Binary Arithmetic Coding (CABAC) as a normative part of the new ITU-T/ISO/IEC standard. By joining an adaptive binary arithmetic coding technique with context modeling, a high degree of alteration and redundancy reduction is achieved. The CABAC framework also includes a low-complexity method for binary arithmetic coding and probability estimation that is well suited for efficient hardware and software implementations.

b) Huffman Encoding :

Table 1:Huffman Coding

Original Source		Source Reduction				
Symbol	Probability	Code	1		2	
A2	0.5	1	0.5	1	0.5	1
A4	0.1875	00	0.3125	01	05	0
A1	0.1875	011	0.1875	00		
A3	0.125	010				

In table 1 the original set of source symbols and their probabilities are ordered from top to bottom in terms of decreasing probability values. To form the first source decrease, the bottom two probabilities 0.125 and 0.1875 are combined to form a multiple symbol with probability 0.3125. This multiple symbol and its associated probability are places in the first source reduction column so that the probabilities of the reduced source are also ordered from the most to the least probable. This process is then repeated until a reduced source with two symbols is obtained.

The term refers to encoding a source symbol (such as a character in a file) use a uneven length code table, where the variable-length code table has been consequent in a particular way based on the predictable probability of occurrence for each possible value of the source symbol. It uses a precise method for choosing the representation for each symbol, resulting in a prefix code that state the most common source symbols using shorter strings of bits. The Huffman algorithm is mostly based on statistical coding, which means that the probability of a symbol has a straight bearing on the length of its representation[6].

Steps:

1. Arrange the symbol probabilities in a decreasing order.
2. While there is more than one node :
   - Merge the two nodes with the smallest probability to form a new node whose probability is the sum of the two merged nodes.
   - randomly assign 1 and 0 to each pair of branches merging into a node.
3. Read sequentially from the root node to the leaf node where the symbol is located.

Spiht Coding Algoritham :

SPIHT (Set Partitioning In Hierarchical Trees) [7] is a very fast and among the best image compression algorithms. SPIHT and Huffman are combined to produce a better compression. Wavelet transform is used to produce a better localization property in the time and frequency domain. It is superior to Fourier and Discrete Cosine Transform (DCT) It has been widely applied and developed in image processing and compression. Encoding is able to end at any location, so it allowed achieving exact rate or deformation. This technique does not need to involve pre-stored codebook. It does not need any feedback knowledge of original image.

Wavelet Transform :

Wavelet based techniques for image compression have been increasingly used for image compression. [8] The wavelet uses subband coding to selectively eliminate different subbands from the original image. Quantization technique is applied to the given subband to give the higer compression. Smoothness area can be handled by wavelet filters. The wavelet filters are designed so that the coefficients in each sub band are almost uncorrelated from the coefficients in other sub bands [9]. The wavelet transform gains better energy compaction than the DCT and hence can help in providing better compression for the same Peak Signal to Noise Ratio (PSNR). A lot of research has been done on the performance comparison of the Discrete Wavelet Transform(DWT) and DCT for image compression. A comparative study of DCT and wavelet based image coding can be found in [10]. The Embedded Zero tree Wavelet or popularly known as EZW is an efficient coding scheme developed by Shapiro .EZW based on the multi-resolution nature of wavelet transforms. The resulting algorithm produce a better performance at low bit rates. The EZW marked the beginning of a new era of wavelet coding. The two features of the EZW coding are efficient map coding and successive approximation quantization. EZW produce the energy compaction properties and the self-similar and hierarchical properties of the wavelet transform. Inter band prediction is used to code the positions of the significant coefficients. The EZW algorithm does not code the location of significant coefficients but instead codes the location of zeros. The EZW algorithm was further extended by Amir et. al to give a new scheme called the Set Partitioning in Hierarchical Trees (SPIHT) [11]. SPIHT achieved better performance than the EZW. SPIHT does not to use the arithmetic encoder. The SPIHT uses a more efficient subset partitioning scheme. According to this, even binary encoded transmission achieves almost similar performance compared to EZW. The wavelet transform outperforms the DCT by around 1 dB PSNR. Wavelet based JPEG compression increase the PSNR by 1 dB than JPEG. DCT-Based Embedded Image coding has been suggested in [12]. The modified EZW algorithm is based on the fact that the 8 x 8 DCT of the image can be viewed as a 64-subband decomposition. The computational complexity of this algorithm is they are not in resolution scalable. EBCOT (embedded block coding with optimized truncation) proposed by Taubman is both signal to noise ratio and resolution scalable. This algorithm is based on block that is it encodes the blocks independently (Embedded block based coding). Due to this, a separate section of interest (ROI) can be decoded separately without decoding the complete image. Also the embedded bit stream includes the information about the number of bits to be decoded, to give the optimal reconstructed quality at a given bit rate

IV. Wavelet Transform Based Embedded Zerotree Coding

Wavelet transform scheme efficiently position the DWT coefficients to code and compress them . Four different type of nodes are used to represent the symbols. (ps, ns, ztr and iz) in the dominance table. The significance table contains the elements 0 and 1. Arithmetic coding of the dominance table and the significance table together achieved better compression ratio. In this case only 4 symbols were used to represent all the different kinds of symbols in the dominance table and the significance table.The main advantage is the arithmetic encoding used in the encoding part.

V. Color Transform :

The purpose of this paper is to develop a hierarchical prediction methods in lossless compression are based on the raster scan prediction which is some times incompetent in the high frequency region.In the hierarchical prediction context , the edge directed predictor is used . The compression of color images RGB is first altered to YCuCv by an Reversible Color Transform (RCT) [13].

a) *Rct*

The integer color transform is a reversible operation that can transform one color coordinate into another and both the inputs and the outputs are of integer forms.

Integer color transform can be implemented by time and accuracy. Moreover, use the new criterion, bit addition, to measure the performance of the integer color transform. In the proposed method, "Hierarchical decomposition and pixel prediction " the reversible color transform (RCT) is used for providing higher accuracy.

Four - Channel Reversible Color Transform :

One of the image data compression is RGB color space. Typical scenarios include the generation of four color CMYK [14](cyan, magenta, yellow, and black) . In that situation compression of the image data is desirable, to decrease file size or network bandwidth. Thus, in this section the discussion variations of the YCoCg transform those are appropriate for CMYK data. The CMYK format was developed for printing with four ink colors. The main benefit of specifying the black channel separately is that better rendition of black or dark tones can be directly achieved with the use of black ink, rather than relying on a precise mixture of magenta, cyan, and yellow to make black. The CMY colors are usually the complement of RGB colors, like

$$c = N - R$$

$$m = N - G$$

$$y = N - B$$

Where assume that RGB and CMYK values are in the range $[0\ldots N]$ (for 8-bit data, $N=255$). The k (black) channel is usually computed by using this formula.

$$k = f\left(\min\{c, m, y\}\right)$$

VI. Hierarchical Decomposition And Pixel Prediction

The resulting channels Cu,Cv have different from the statistics of Y , and also different from the original color valued *Red, Green,* and *Blue.* In the chrominance channels, the overall signal variation is suppressed by the color transform, but the signal variation (prediction error) is large in edge boundaries. [15]Hence, the prediction errors in a chrominance channel are much reduced in a smooth region, but remain relatively large near the edge or within a texture region. For the efficient lossless compression, first must estimate the prediction error in context, along with the perfect prediction. For this, propose a hierarchical decomposition scheme in which shows that pixels in an input image X is separated into two sub images: an even sub image Xe and an odd sub image Xo. Then, Xe is encoded first and is used to predict the pixels in Xo. Decomposition image Xe is also used to estimate the of prediction errors of Xo. In actual implementation, Xe is decomposed once more as will be explained later.

VII. Proposed Coding Scheme

By using rgb2yc0bcr tool in Matlab the original image composed into Y ,Cb,Cr components. Normally Y component is encoded by any of the gray scale image compression algorithm.

Original Image

Figure 1 : Original Image

Sample Bitmap input image is shown in Figure 1.

Y,cb,cr Components

Figure 2: Y, Cb, Cr Components

In Fig 2 the original input image is converted into y, C_b, C_r Components.

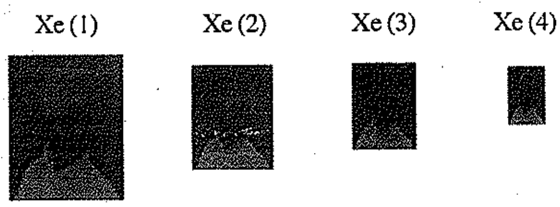

Figure 3: Even row decomposition (Odd row decomposition same as even row decomposition)

In Fig 3, the Channels (Cb,Cr) is Compressed by our proposed algorithms. The image is decomposed into even and odd row of sub images.

Likewise odd row sub images can be calculated. For each pixel Xo(i,j) in Xo, the horizontal predictor Xh(i,j) and vertical Predictor Xv(i,j) are defined as

Xh(i,j)=Xo(i,j-1)

Xv(i,j)=Round((Xe(i,j)+Xe(i+1,j))/2

The vertical predictor is more often correct than the horizontal one .The horizontal Predictor is more accurate only when there is a strong horizontal edge.

When |Xo(i,j)-Xh(i,j)| is much smaller than |Xo(i,j)-Xv(i,j)| then the Horizontal predictor is Choosen otherwise vertical predictor is choosen.

VIII . Experimental Results

Compression method may be the CALIC , which shows higher coding gain than the JPEG-LS (or LOCO-I) , at the cost of higher computational complexity. For the compression of color image, the JPEG2000 and JPEG-XR lossless provide better coding gain than the independent encoding of each channel by CALIC and also than the encoding by CALIC after RCT. Hence compare JPEG2000 and JPEG-XR. Experiments are summarized in Table III. that different color transforms are used in each of the methods stated above. Hence, for fair comparison, and also perform experiments with the same RCT, the results of which are denoted as "JPEG2000 with RCT and "JPEG-XR with RCT " in Table II. It can be seen that the recent RCT improves the coding gain though not significant. On the average, the proposed algorithm improves 7.10% and 18.89% over JPEG2000 and JPEG-XR [16] respectively.

Table II : Average of Compressed Bit Rates (bpp) For 24 Kodak Images

COMPRESSION	BPP
JPEG2000	9.5353
JPEG2000 WITH RCT	9.4586
JPEG-XR	10.9214
JPEG-XR WITH RCT	10.8587
Proposed	**8.8587**

In table II the proposed method is also tested on some kodak images. On the average, the proposed algorithm improves 7.10% and 18.89% over JPEG 2000 and JPEG-XR

Table III:Compressed Bit Rates Of Classic Images

	Size	CALIC	JPEG2000	JPEG-XR	Proposed
Lena	512*512	**13.1787**	13.5848	14.0942	13.6461
Peppers	512*512	**13.8661**	14.8000	15.3245	15.2102
Mandrill	512*512	18.1511	**18.0939**	18.2553	18.5305

On the set of classical test images such as Lena,peppers, and Mandrill, even the chennal independent CALIC sometimes perform better than JPEG2000 and our algorithm as shown in Table III.

Table IV : Compressed Bit Rates For The Digital Camera Images

Images	Size	JPEG2000	JPEG-XR	Proposed
Ceiling	4288*2848	7.5571	8.8331	**7.2080**
Locks	4288*2848	7.4574	8.8296	**7.1623**
Berry	4288*2848	7.2468	8.6646	**6.8917**

In addition, experiments for images from commercial digital cameras are also conducted,and the results are compared in table IV.The images are captured with NIKON D90.On the average, the proposed algorithm produces 5.52% less bit than JPEG2000 lossless.

IX. Conclusion

Our proposed algorithm is a lossless color image compression methods based on a hierarchical prediction scheme and context adaptive arithmetic coding.The proposed method and several conventional methods have been tested on the Kodak image set, and digital camera images,and it is shown that average bit rate reductions over JPEG2000.It is also noted that the proposed method does not always perform for every set of images.The proposed hierarchical encoding scheme sometimes works better and sometimes worse than the conventional methods, depending on the image sets and also depending on the channels(Y,Cu,Cv).It is also true for every compression algorithm.

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