AN ENHANCED LOSSLESS IMAGE COMPRESSION BASED ON HIERARCHICAL PREDICTION CONTEXT ADAPTIVE CODING

R. Navaneethakrishnan[1], M.H. Mohamed Faizal[2], S. Pradeep[3]

[1]Department of Computer Applications ,

[2,3]Department of Electronics and Communication Engineering

Bharathiyar College of Engineering and Technology, Karaikal (India)

ABSTRACT

To display high bit resolution images on low bit resolution displays, bit resolution needs to be reduced. Towards achieving a reduced bit rates and high compression gain, an enhanced method for compression of various color images are presented, which is based on hierarchical prediction and adaptive coding. An RGB image is first transformed to YCbCr by a reversible color transform and a various conventional lossless grayscale image compression techniques which encodes Y component. A hierarchical decomposition that enables the use of upper pixels, left pixels, and lower pixels for the pixel prediction to encode the chrominance channel. The prediction error is measured based on context model and the adaptive coding is applied to the error signal. Parameters such as peak signal to noise ratio, encoding, decoding time and bit rate have been evaluated and it is exposed that the proposed method further reduces the bit rates compared with JPEG2000 and CALIC.

Keywords-Context adaptive arithmetic coding, Hierarchical decomposition,Lossless RGB image compression, Pixel prediction, Reversible color transform.

I.INTRODUCTION

Along with the increasing attractiveness of digital cameras, the number of digital photos is considerably growing, and the resolution of digital images is also quickly increasing. In order to handle a huge amount of data, different image compression methods have been proposed over the past twenty years. Image compression can be classified into lossy and lossless compression. The lossy compression methods achieve high compression gain at the cost of image quality degradation. Lossless compression, which allows the original data to be exactly reconstructed, has been gaining a high popularity these years. Hence efficient lossless compression become more significant, though the lossy compressed images are usually satisfactory in many cases.

Along with the consistency, many lossless image compression algorithms have been proposed. Among a variety of algorithms, the most extensively used ones are Lossless JPEG LS [5], JPEG [2], LOCO-I [7], CALIC [3], JPEG2000 [6] and JPEG XR [14]. LOCO is the technique at the core of the new ISO standard for lossless and near-lossless compression of continuous-tone images. Context adaptive lossless image codec (CALIC) obtains higher lossless compression of continuous tone images than other techniques. A distinctive feature of CALIC is the use of a large number of modeling contexts to condition a non linear predictor and make it adaptive to varying source statistics. In the procedure of JPEG standardization, the LOCO-I and CALIC were developed ,where most thoughts in LOCO-I are accepted for the JPEG-LS standard though the CALIC provides better compression act or performance at the cost of more computations.

For the lossless color image compression, the RGB components are first decorrelated by a reversible color transform, and each of the transformed components are separately compressed by the above mentioned methods. Generally, RGB image has high density and highly correlated and it cannot be compress capably and it is decorrelated to YCbCr (Combination of luminance and chrominance image) by using reverse color transform.

The dissimilarity between Y$CbCr$ and RGB is that $YCbCr$ represents color as brightness and difference between two color signals, while RGB represents color combination as red, green and blue. Y is the brightness (luma), Cb is blue minus luma (B-Y) and Cr is red minus luma (R-Y) in $YCbCr$. However, in the case of lossless compression, most color transforms cannot be used due to their non invertibility with integer arithmetic . Hence an invertible edition of color transform, the reversible color transform (RCT) was mentioned and used in JPEG2000 [6]. Many researchers have been there for finding better RCTs [11], among which we take up a transform proposed in [12] because it approximates the conventional $YCbCr$ transform very well. The idea of this paper is to expand a hierarchical prediction scheme and most of an existing prediction method in lossless image compression are based on the conventional raster scan prediction which is sometimes bungling in the high frequency region. The "hierarchical" prediction for the compression was already proposed in [1], but only pixel interpolation is used here. An edge detection and context adaptive model for this hierarchical scheme is designed in this paper.

For the prediction of a pixel to be encoded, here we propose a method that can use lower row pixels as well as the upper and left pixels For the compression of color images, the RGB is first altered to $YCuCv$ by an RCT and Y channel is determined by a conventional grayscale image compression algorithm. The signal variation is generally much smaller than that of RGB, but still large near the edges in the case of chrominance channels ($CuandCv$).For more precise prediction of these signals, and also for accurate modeling of prediction errors, we use the hierarchical scheme, the chrominance image is splitted into two subimages; i.e. a set of even numbered rows and a set of odd numbered rows respectively. Once the even row subimage Xe is pre-arranged, we can use all the pixels in $Xe$for the prediction of a pixel in the odd row subimage Xo. In addition, since the statistical properties of two subimages are not much dissimilar, the probability density function of prediction errors of a subimage can be exactly modeled from the other one, which contributes to better context modeling for arithmetic coding. Various kinds of images are performed, and it is shown that the proposed method provides higher coding gain than JPEG2000 and JPEG-XR (existing methods) in many cases.

II.HIERARCHICAL SCHEME AND PIXEL PREDICTION

In this hierarchical decomposition,the chrominance channels *Cu* and *Cv* which results from the RCT usually have different figures from *Y (*luma),and also different from the original color planes *R*, *G*, and *B*. The overall signal variation is concealed by the color transform in the chrominance channels, but the variation is still large near the object boundaries. Consequently, the prediction errors in a chrominance channel are much reduced in a smooth region, but remain reasonably great near the edge or within a texture region. The pdf of prediction error for better context modeling, along with the accurate prediction is estimated for the efficient compression.Here, we propose a hierarchical decomposition scheme that is pixels in an input image X is splitted into two subimages: an even subimage Xe and an odd subimage Xo. An even subimage is encoded first and is used to predict the pixels in odd subimage Xo In addition, Xe is also used to find the statistics of prediction errors of Xo.For the compression of Xo pixels using Xe, directional prediction is worked to avoid large prediction errors close to the edges. For each pixel, the horizontal predictor $\hat{x}h(i, j)$ and vertical predictor $\hat{x}v(i, j)$ are defined as

$$\hat{x}_h(\text{i,j})=x_0(i, j-1)$$

$$\hat{x}_v(i,j) = round(\frac{x_e(i,j)+x_e(i+1,j)}{2}) \rightarrow \text{(a)}$$

Algorithm (a) : To find the direction of i,j

if $|x_o(\text{i,j})\text{-}\ \hat{x}_h(i,j)|+T_1 < |x_o(\text{i,j})\text{-}\ \hat{x}_v(i,j)|$ then

dir(i,j) ←H

else

dir(i,j) ←V

end if

and one of them is selected to predict $xo(i,j)$. The most important one is the horizontal predictor will be more accurate only when there is a strong horizontal edge.

To implement this idea, we define a variable for the direction of edge at each pixel dir(i, j), which is given either Horizontal or Vertical. To decide the direction of i, j and it is explained in Algorithm (a).

Algorithm (b) : To calculate the overall pixel prediction

if dir(i-1,j)=H or dir(I,j-1)=H then

Calculate dir(i,j) by algorithm (a)

Program dir(i,j)

if dir(i,j)=H then

$\hat{x}_o(i,j) \leftarrow \hat{x}_h(i,j)$

else

$\hat{x}_o(i,j) \leftarrow \hat{x}_v(i,j)$

end if

else

$\hat{x}_o(i,j) \leftarrow \hat{x}_v(i,j)$

end if

III. PROPOSED CODING SCHTEME

In this proposed coding section, the overall procedure of image compression has been explained. First,an input RGB color image is transformed into $YCuCv$ which is a combination of luminance and chrominance color space by an reversible color transform. The conventional compression methods such as CALIC and JPEG-LS which encodes the luminance image Y .The chrominance channel Cu and Cv are encoded using the method hierarchical decomposition and pixel prediction.

First, a chrominance part $X0 \in \{CuCv\}$ is decomposed row by row into an even subimage $X0(1)$ and an odd subimage $Xo(1)$.The odd subimage $Xo(1)$ is predicted and encoded using even subimage $Xe(1)$, as described in Section(b) and then a subimage $Xe(1)$ can be further divided column by column into the even subimage $Xe(2)$ and the odd subimage $Xo(2)$.

The effective encoding of the prediction error $e(i, j)$ in the predictive lossless image compression plays a vital role. Though the proposed pixel prediction method frequently generates small prediction errors due to the RCT, there are still comparatively large errors close to the edge or texture region, which degrades the performance of compression

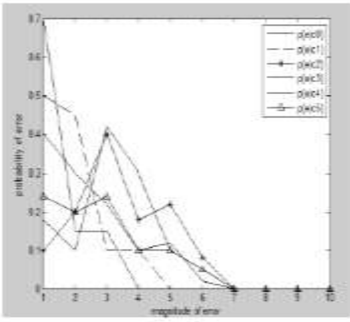
For the efficient compression, prediction errors should well be explained by a correct model. We construct the prediction error as a random variable with probability density function $P(e|Cn)$, where $Cn$is the coding local activity that reflects the magnitude of edges and textures. In particular, Cn is denoted as the level of quantization steps of pixel activity $\sigma(i, j)$ defined as $\sigma(i, j) = |xe(i, j) - xe(i + 1, j)|$. Figure (1) shows an input image and it compares the magnitude of an error with probability of an error and the local activity of a subimage called as (context), and $P(e|Cn)$ for several Cn. It explains the statistical property of prediction error very well, in that the magnitude of error is large only when the local activity (context) is strong. Therefore the proposed technique can be effective for the compression with adaptive arithmetic coding.

IV. SIMULATION RESULTS

The algorithm is applied on various test images, which is widely used for the lossless compression. In all the simulation , the parameter T1 in Algorithm (b) and number of contexts are assigned to 2 and 4.The conditional probability density function has been simulated as shown in Fig.1.The tool used for simulation is Matlab with operating system Windows Xp,7.

The classic images which has a combination of Red, green and blue and it is transformed into $YCbCr$ then compression is done and arithmetic coding has been applied to find bit rate and PSNR. The simulation results are summarized in Table I which compares the compressed bit rates with existing methods such as CALIC,JPEG 2000 and JPEG XR It shows higher compression gain than the JPEG-LS and LOCO-I. at the cost of higher computational complexity.For the lossless compression of color image, the JPEG2000 and JPEG-XR [14] provides better coding gain than CALIC and also than the encoding by CALIC after RCT.

a) Input Image b) Context



(c) Conditional Pdf

Fig . 1 An example of local activity(context) and probability of error depending on context.

Table I

Comparison Of Compressed Bit Rate Per Pixel For Classic Images

	SIZE	CALIC	JPEG2000	JPEG XR	PROPOSED
Lena	512×512	13.1787	13.5848	14.0942	13.5162
Peppers	512×512	13.8661	14.8000	15.3245	9.07031
Eye	512×512	18.1511	18.0939	18.2553	10.0641
Strawberry	512×512	14.9567	11.1612	15.1408	12.8927

The peak signal to noise ratio is measured for various images which are summarized in Table II.

Table II

Calculation of Peak Signal to Noise Ratio (DB) For Classic Images

	Size	Proposed
Lena	512×512	13.550032
Peppers	512×512	7.731209
Eye	512×512	7.196240
Strawberry	512×512	6.605782

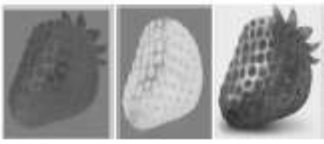


Fig. 2 . The Classic images set 1

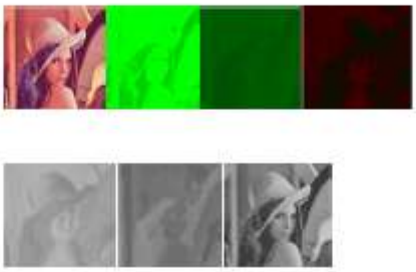


Fig. 3. The Classic images set 2

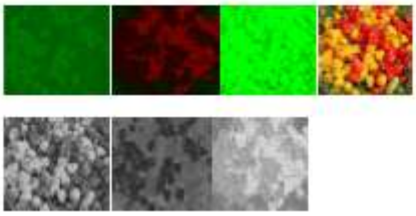


Fig. 4. The Classic image set 3

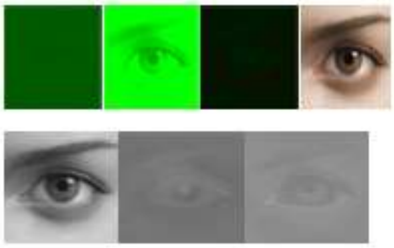


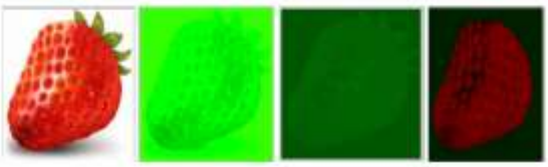
Fig. 5. The Classic images set 4

Table III

CPU Times (Seconds) – Encoding and Decoding Time

	Encoding time	Decoding time
Lena	11.657924	12.908306
Peppers	12.148840	13.023052
Eye	8.7665245	9.644510
Strawberry	10.516191	8.009343

COMPRESSED IMAGES



Finally, for set of images the encoding time and decoding times are measured which are summarized in Table III. Since this method employs JPEG2000 and needs additional steps for hierarchical prediction and context modeling, it requires slightly more computation time than the JPEG2000.

Performance Analysis

(i) **Mean Square Error**

Mean square error is defined as cumulative error between original image and compressed image

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

(ii) Peak Signal To Noise Ratio

It is used to measure the quality of reconstruction of lossy and lossless compression (e.g., for image compression). The amount of signal in the original data, and the noise is the error introduced after compression. When comparing compression codecs, PSNR depends on human perception of reconstruction quality. The reconstruction quality will be good if system has higher PSNR.PSNR is most measured through the mean squared error can solve the unattended RTS problem and improve the pipeline efficiency.

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

V. CONCLUSION

An enhanced lossless RGB image compression based on hierarchical prediction and context adaptive coding has been proposed to reduce the bit rate and to achieve high compression gain.The color image is first converted to $YCuCv$ by reversible color transform in which the chrominance channel is encoded based on pixel prediction , hierarchical decomposition and conventional compression method encodes luminance component Y. The prediction error is measured based on context model and the adaptive coding is applied to the error signal. Parameters such as peak signal to noise ratio, encoding, decoding time and bit rate have been evaluated. The proposed method and several conventional methods have been tested on the various images and shown that average bit rate reductions over JPEG2000 for these set of images are shown to be 7.20%, 13.22% and 6.1%

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