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Color Image Compression of Inter-Prediction Base

Asst. Prof. Dr. Ghadah Al-Khafaji[1]*; Marwa Bassim[2]*
[1]Department of Computers, College of Science, University of Baghdad, Baghdad, Iraq
[2]Department of Computers, College of Science, University of Baghdad, Baghdad, Iraq
[1] Hgkta2012@scbaghdad.edu.iq, hgkta2012@yahoo.com
[2] mbj_real@yahoo.com

Abstract In this paper an efficient hybrid lossless/lossy color image compression of inter-prediction base is introduced. The proposed technique uses the RGB and YCbCr color basis that simply based on color inter-prediction model of non-reference color bands lossily and the reference band losslessly respectively using the Huffman coding technique. The results are promising in terms of compression ratio and preserving quality, also the results indicated higher performance of RGB color base compared to YCbCr color transformation model.
Keywords: lossless/lossy, color image compression, inter-prediction base.

1. Introduction

Compression systems have become an increasingly intensive and important research area over the last thirty years, especially with the massive continuous revolution in communications technology and computer hardware that has lead to the construction of universally accepted standard systems that play a key role in the development of compression systems. These combine efficiency, ease of use and speed with the ability to fulfill a variety of requirements [1].

In general image compression techniques are classified into two groups, depending on the redundancy type(s) removal- on the basis of statistical redundancy alone or on the basis of psycho-visual redundancy, either solely or combined with statistical redundancy(s), corresponding to the *lossless* and *lossy* respectively [2]. As mentioned previously, the techniques can be separated into two categories of *reversibility* and *irreversibility* base, respectively.

The *lossless* also called information preserving or error free techniques, based on utilizing the statistical redundancy, where the decoded (compressed) image is identical to the original uncompressed image without losing information and low compression ratio. On the other hand, the *lossy* type remove content from the image, which degrades the compressed image quality with high compression ratio, and are based on the utilization of psycho-visual redundancy, either solely or combined with statistical redundancy [3, 4, 5].

Color images usually decomposed into *R* (Red), *G* (Green) and *B*(Blue) bands that are highly correlated, and requires a large amount of information that affected storage space and transmission rate, thus data compression techniques become an urgent requirement [6]. The initial work on color compression systems was based on utilizing the three bands solely, namely compress each band separately without considering the spectral correlation embedded between the neighbouring bands (i.e. use the same image compression techniques triple times on each band separately), which this method was simple to implement with low compression results, includes Block Truncation, Discrete Cosine Transform (*DCT*), and Wavelets, where the main drawbacks of this direct technique are still suffering from the existence of spectral redundancy, inefficient of low compression ratio, huge processing and computation[7]. Other efforts aimed at improving the color compression mechanism, using color transformation space that exploits the spectral redundancy efficiently, such as [8, 9] which combined *DCT* and the *YCbCr* transformation, other exploits the wavelet transform with color spaces of *YUV* and *YCbCr* [10, 11, 12], but with increasing demand on color applications, the challenge and necessity of improving color compression system performance grew.

Currently, prediction techniques of inter base represents the solution of color image compression problem that resemble a video compression system, since it would needs to identifies the source band in the color image, which implicitly means removing certain bands and compensating for these with predicted bands from the source, in other words, the researchers adopted another concept for compressing color images based on prediction scheme [7], where [13,14,15] utilize color prediction technique between image bands where color map is generated based on color difference by using the predefined threshold.

This paper is concerned with improving the color compression system using the inter prediction base efficiently to overcome the spectral redundancy embedding problem along the primitive or nature of *RGB* base color and transformed one of *YCbCr* color transformation base.

2. The Proposed System

The main concerns of the proposed system are to incorporate the inter-prediction base between color image bands of *RGB* base and *YCbCr,* where implementation discussed in the following sections below.

2.1 Inter-Prediction Color Compression with RGB Color System base

Color images, typically composed of *R, G* and *B* signals, have considerable correlations between each signal. Therefore exploiting such correlations is essential for efficient coding of color images.

The inter-prediction coding to remove the spectral redundancy efficiently based on the principle of modelling. The implementation of the proposed system is explained in the following steps, the layout is illustrated in figure (1):

Step 1: Load the input uncompressed color image *I* of *BMP* format of size $N \times N$.

Step 2: Split the *I* into its bands (I_R, I_G, I_B), each of size $N \times N$ of high spectral redundancy, where I_R, I_G, I_B corresponding to *R,G and B* image bands.

Step 3: Compute the cross correlation between the color bands according to equation (1), namely finding the cross correlation between the $\mathrm{Cross}_{(IR,IG)}$, $\mathrm{Cross}_{(IG,IB)}$, and $\mathrm{Cross}_{(IR,IB)}$ then choose the highly one corresponding to reference band.

$$\mathrm{Cross}_{(\mathrm{xband,yband})} = \frac{\sum_{x=0}^{n-1}\sum_{y=0}^{n-1} C_{(\mathrm{xband,yband})}}{\sqrt{\sum_{x=0}^{n-1}\sum_{y=0}^{n-1} C_{(\mathrm{xband,yband})} C_{(\mathrm{xband,yband})}}} \ldots\ldots.(1)$$

Where $\mathrm{Cross}_{(\mathrm{xband,yband})}$ corresponds to the cross correlation measure between the xband and yband.

Step 4: For each non-reference band, apply the inter-prediction base technique using the reference band along with seed value of current band (non-reference) to estimate the current band as illustrated in figure(2).

$$\tilde{X} = \frac{W + (X_r - W_r) + N + (X_r - N_r)}{2} \dots\dots (2)$$

Where X is the current pixel value that depends on neighboring pixels, This predictor estimates $\tilde{X}$ using neighboring intensity ,values from the current band (*W* and *N*) and from a reference band (*Xr*, *Wr* and *Nr*) [13].

Step 5: Find the residuals for the non-reference bands, as a difference between the original and predicted band (see equation 3), then quantized/ dequantized uniformly using scalar uniform base, such as:

$$Res(i,j) = Refrence_{band}(i,j) - Predictednon\,Refrence_{band}(i,j) \dots\dots\dots\dots (3)$$

$$Res\,(i,j) = round\left(\frac{Res}{QS_{Res}}\right) \rightarrow ResD = ResQ \times QS_{Res} \dots\dots\dots (4)$$

Where *ResQ is* quantized residual image, QS_{Res} *is* quantization step of residual image, *ResD is* dequantized residual image.

Step 6: Encode/decode the compressed information of inter-prediction technique along with the reference band using Huffman coding techniques.

Step 7: Reconstruct the decoded compressed image $\hat{I}(i,j)$, by first rebuild each band separately by the predicted image, followed by adding the reconstructed bands to reconstruct the compressed or decoded image.

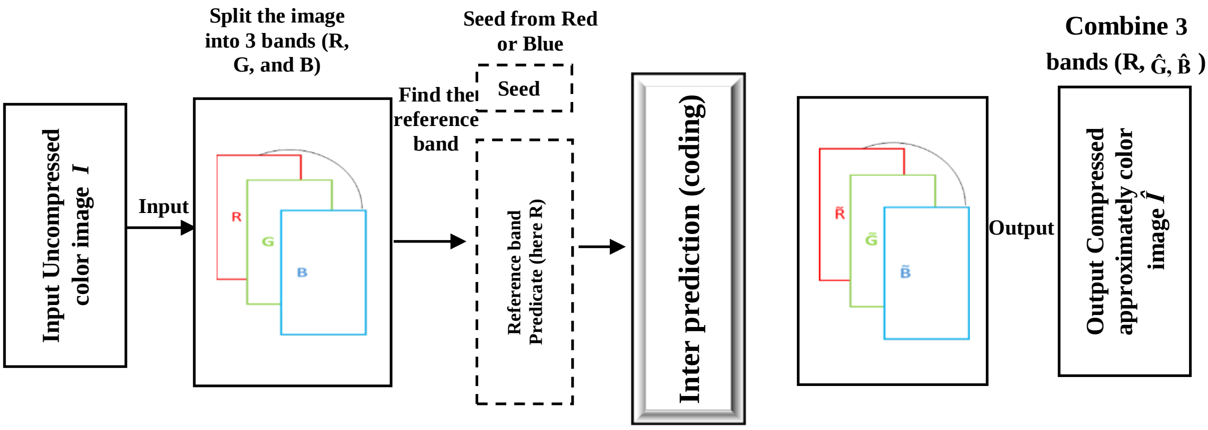

Figure (1): The inter-prediction color of RGB base, where *R* band utilized as a reference band that codded losslessly using the Huffman coding techniques.

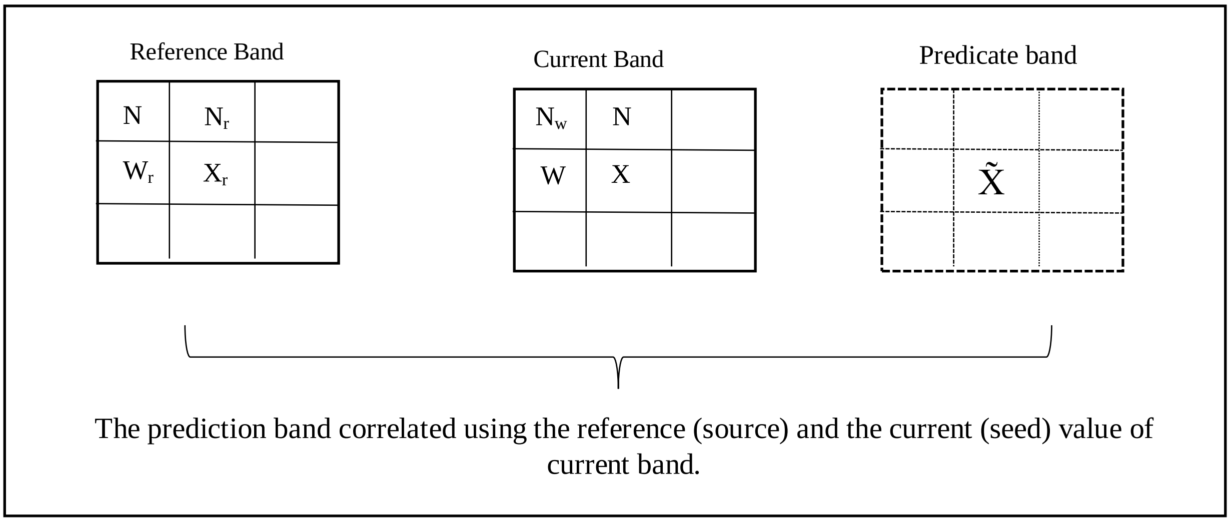

Fig. (2): Inter prediction color base [13].

2.2 Inter-Prediction Color Compression with YCbCr transform Color System base

This technique is identical to the color inter-prediction coding of *RGB* base discussed above, but here with the extension into color transformation model (see figure 3), in other words exploits the color space conversion to eliminate the spectral redundancy between image color bands of *RGB* base before applying the inter-prediction coding techniques, here the *YCbCr* color space adopted, where *Y* is corresponds to the luminance component, *Cb* and *Cr* are the chrominance components, as in equation (5), the steps illustrated in figure(3).

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \dots\dots\dots..(5)$$

Also, we have to mention here that the inverse conversion is essential to reconstruct the compressed image, such as:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.0 & 1.4021 \\ 1 & -0.3441 & -0.7142 \\ 1 & 1.7718 & 0.0 \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} \dots\dots\dots\dots\dots.. (6)$$

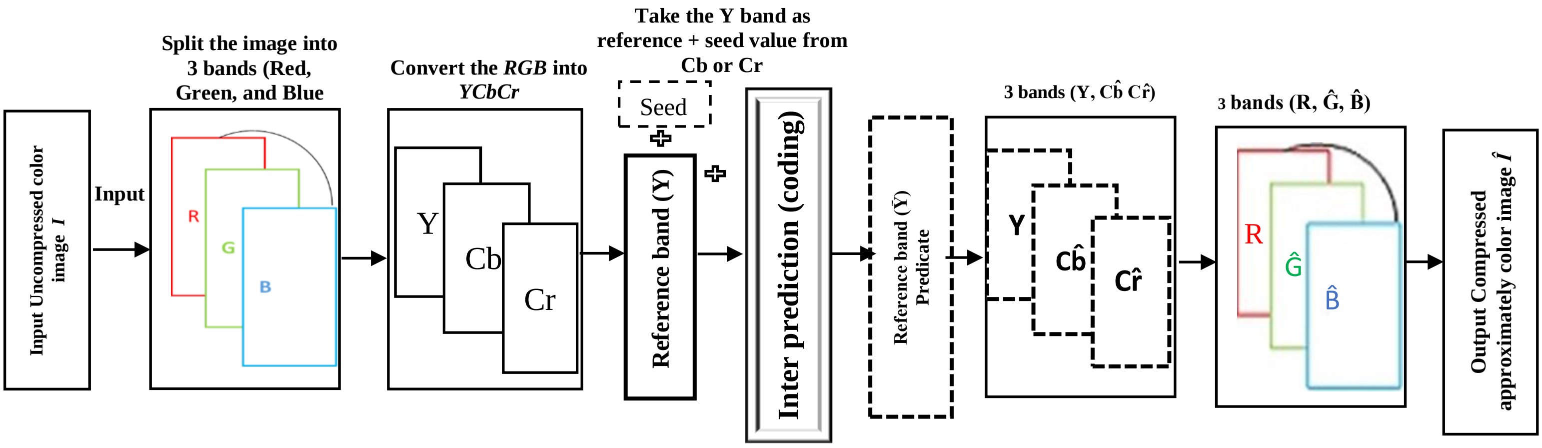

Figure (3): Inter-prediction coding with YCbCr color transformation, in which the Y band utilized as a reference band that coded losslessly using the Huffman coding techniques.

3. Experimental Results

For testing the proposed system performance; three standard color images adopted, as shown in figure 4 (a) 'Lena', (b) 'Girl' and (c)'Pepper'. Lena is characterized by a wide variety of image details, while the two images less variations in image detail, having large smooth areas with low detail. All the images are a square of the same size, 256×256, and color of (24 bits/pixel).

a b C

Figure (4): The three tested images of size 256×256, (a) Lena image (b) Girl image and (c) 'Pepper'image.

The tests have been performed on inter-prediction base using block of size 8x8, and the values of quantization steps of residual images are selected between 5 to 70. The compression ratio which is the ratio of the original image size to the compressed size along with the PSNR between the original image I and the decoded image $\hat{I}$ was adopted as fidelity measure due to popularity and simplicity as in equation (8).

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \qquad (7)$$

$$MSE(I,\hat{I}) = \frac{1}{N \times N} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \left[\hat{I}(i,j) - I(i,j)\right]^2 \quad \text{................(8)}$$

I(i, j) represent an input image (original image), and $\hat{I}(i,j)$ denotes an decoded image each of square size $N \times N$.

The cross-correlation of the tested images using the RGB color system and the YCbCr of the transformed base, illustrated in tables (1 and 2) respectively.

Table (1): The cross correlation values between the color bands in *RGB* of the three tested images.

Test images	cross correlation values between the color bands in *RGB* color system		
	Cross-Corr.(R,G)	**Cross-Corr. (R,B)**	**Cross-Corr.(B,G)**
Lena	0.8895	0.7089	**0.9222**
Girl	0.7712	0.6819	**0.9126**
Pepper	**0.6522**	0.3260	0.2732

Table (2): The cross correlation values between the color bands in YCbCr of the three tested images.

Test images	cross correlation values between the color bands in *YCbCr* color system		
	Cross-Corr (Y,Cb)	**Cross-Corr (Y,Cr)**	**Cross-Corr (Cb,Cr)**
Lena	**0.7484**	0.0866	0.4783
Girl	**0.2802**	0.0652	0.5426
Pepper	**0.6615**	0.2587	0.4759

The results shown in tables above, clearly shown the correlation embedded between the RGB base, that eliminated when exploited the YCbCr due to removing the spectral redundancy between the color bands, that directly affected the selection (choosing) the reference band, namely in RGB color system, where the spectral redundancy is high the reference band vary according to image details (characteristics) (i.e., the reference band may be R or G or B) , whereas in YCbCr the reference band corresponds to Y band only.

The experimental results are listed in table 3 for the *RGB* and YCbCr transformed bases respectively, clearly shown the trade off or the inverse relation between the compression ratio and the decoded image quality, where for low compression ratio attains the high *PSNR* value, and vice versa.

Table (3): Comparison performance between inter prediction base of *RGB* and (*YCbCr*) color system for tested images.

Tested Image	Quantization Steps of Residual	Proposed System performance of inter-prediction base			
		RGB base		YCbCr base	
		PNSR	CR	PNSR	CR
Lena	5	46.0552	24.0823	39.7085	19.8956
	10	40.2142	26.1308	33.7556	23.4001
	20	35.3361	27.6135	28.5424	26.1516
	50	31.1352	28.6935	25.8329	28.1593
	70	30.8768	28.9129	25.5756	28.6350
Girl	5	46.2122	18.3266	39.7341	17.6140
	10	39.8420	20.9872	34.0515	20.0825
	20	34.5146	23.0328	29.1299	21.8794
	50	30.7140	24.7992	26.5111	23.4784
	70	30.5846	25.1546	26.2528	23.9474
Pepper	5	47.5829	18.9374	39.9102	18.2518
	10	41.5477	21.4310	34.3654	21.2871
	20	36.2181	22.9307	29.4390	23.2948
	50	30.7485	24.1355	26.5666	25.0904
	70	30.2208	24.4355	26.2091	25.5468

From the test results of the proposed system, the following remarks are stimulated:

1. The inter prediction color compression system technique is characterized by efficiency and simplicity and affected by quantization step of residual image and the image characteristics or details.
2. Certainly the *CR* attained by RGB base is higher than the *YCbCr* base due to the higher spectral redundancy embedded between RGB bands that eliminated when using the transformed color base systems.
3. The choosing (selecting) of reference band depending on the color system exploited, where in RGB vary according to image details (characteristics), while in YCbCr all the information is concentrated in Y reference band.

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