Color Image Compression using Inter-color Correlation

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Abstract

Natural images are characterized by high correlation between their RGB color components. Most representation and compression techniques reduce the redundancies between color components by transforming the color primaries into a decorrelated color space, such as YIQ or YUV. In this paper a different approach to color information analysis is considered. Since the high correlation of color channels implicitly suggests a localized functional relation between the components, it could be used in an alternative framework, by approximating subordinate colors as functions of a base color. This way, only a reduced number of parameters is required for coding the color information. Compression results are presented and compared with JPEG, and the parameters that affect the coding quality are studied and discussed. The results show the advantages of the new correlation-based approach over the YIQ/YUV decorrelation techniques as used in JPEG and related applications.

1. Introduction

As the human visual system is more sensitive to details in luminance than to details in chrominance, the color information can be compressed at a higher rate. The JPEG compression algorithm [1, 7, 9] is a typical example of this approach where the I and Q information of the YIQ representation is encoded separately at lower rates than Y. In doing so it is assumed that the I and Q components contain information that has little or no correlation to the luminance (Y) of the image.

This is not necessarily the case in many images, as can be observed by comparing the I and the Q images to the Y image – usually one can easily recognize the Y image in the I and the Q components when displayed separately. There are, however, other techniques that exploit high correlation between color components [4, 5, 8, 10] instead of decorrelating them. High color correlation suggests that one of the primary colors is an independent variable and the two other components could be represented or approximated as functions of this base color.

The main objective of this work is to develop and introduce a color analysis and compression technique using intercolor correlation [4], and to study the consequences of the interband correlation on image representation. The results are compared to presently available techniques.

2. Color Representation

The basic idea is to select one of the 3 color components R, G, or B as a base-color, and represent the other two components as approximated functions of the base-color [2]. As will be shown in this study, only rough approximation is required for these functions without significant reduction in image quality. The processing steps in the proposed encoder and decoder for color images are described in Figure 1:

1. For each of the color components R, G and B, divide the image into *NxN* blocks. In each block select a base color according to one of the following rules:

    - A fixed color component, usually Green will serve as a base color. The green component is in many cases associated with the intensity of the image, and usually has high correlation with the other 2 components.
    - A variable component, according to the highest correlation to the other two components, or to the highest quality coding (see below).

2. Approximate the subordinate colors using polynomial expansion functions of the base color:

$$C_1 = \sum_{k=0}^{K} P(C_o) = a_k C_0^k + a_{k-1} C_0^{k-1} + \ldots + a_1 C_0 + a_0 \quad (1)$$

and

$$C_2 = \sum_{k=0}^{K} P(C_o) = b_k C_0^k + b_{k-1} C_0^{k-1} + \ldots + b_1 C_0 + b_0, \quad (2)$$

where C_0 is a base color, $C_{1,2}$ are interpolated subordinate colors, K is the order of the polynomial expansion, and a_k and b_k are the coefficients of the polynomial expansion.

Since the polynomial coefficients $\{a_k\}$ and $\{b_k\}$ of adjacent blocks tend to be correlated too, Delta Modulation and Huffman's entropy coding are an efficient way of representation. Additional side information for each block includes indication of the selected base color (if variable) and quantization levels of the polynomial coefficients.

A decompression algorithm can readily reverse the process (Figure 1, right). The decoder first restores the base color, then reconstructs the subordinate colors from the polynomial expansion coefficients using $\{a_k\}$ and $\{b_k\}$ and the decoded base color.

3. Base Color Selection

Instead of the Green component, which is arbitrarily chosen as a base color, two alternative ways to better select a base color in each image sub-blocks are proposed. The first is to select the color component with the highest weighted correlation to the other two components.

It is assumed that since polynomial expansion is used to estimate the subordinate colors, linear approximation of two variables results in a smaller estimation error, if these variables are more correlated. Another option is to select the color component with the lowest secondary colors' reconstruction error for each block. Base color selection is according to the final result and the distortion measure of the compressed images.

This technique requires extra bits to be invested in order to encode the base color index. Using entropy coding [3], however, a significant reduction of bits required for the base color encoding could be obtained.

We conducted the above study on the images 'Lena', 'Peppers', and 'Sail'. The results for Lena are presented in Figure 2. In all the three methods, the color information is based on first-order polynomial approximation. In the proposed algorithm, the error of the linear fit $E(Y/x) = \alpha + \beta x$ is measured according to the energy of the error, by $E = \sum_i^n (y_i - \alpha - \beta x_i)^2 = \sum_i^n \varepsilon_i^2$.

The Least Squares fit method is used for the approximation due to its simplicity. For the purpose of a comparative study, we have also implemented a Least Absolute Deviation regression, as well as using the CIE-LUV and CIE-L*a*b* spaces, however, simulation results show very little difference visually and in image distortion measured by PSNR.

4. Implementation

The proposed technique was implemented using variable base-color selection according to the highest correlation, with first-order polynomial approximation for the two additional components. For comparison, the same image was compressed by the JPEG coding algorithm (Figure 3). The luminance information (Y) of the compressed image was then restored from the original image. This way, only the color information of an image was encoded. Since green is selected as the base-color for

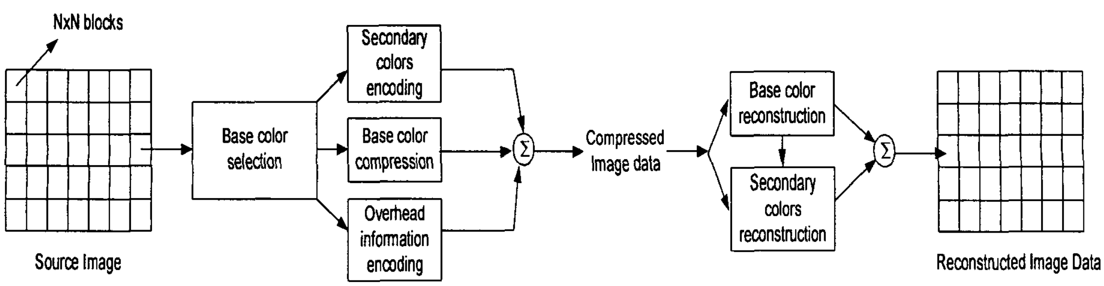

Figure 1. Left: Encoder Block Diagram. The original image is divided into NxN blocks. For each block, a base color is selected, and the other two colors are represented as approximated functions of this base color. Subordinate colors are encoded using the polynomial expansion coefficients. Right: Decoder Block Diagram. The base color is reconstructed from the compressed image data. The other two colors are reconstructed using the base color and the polynomial expansion coefficients.

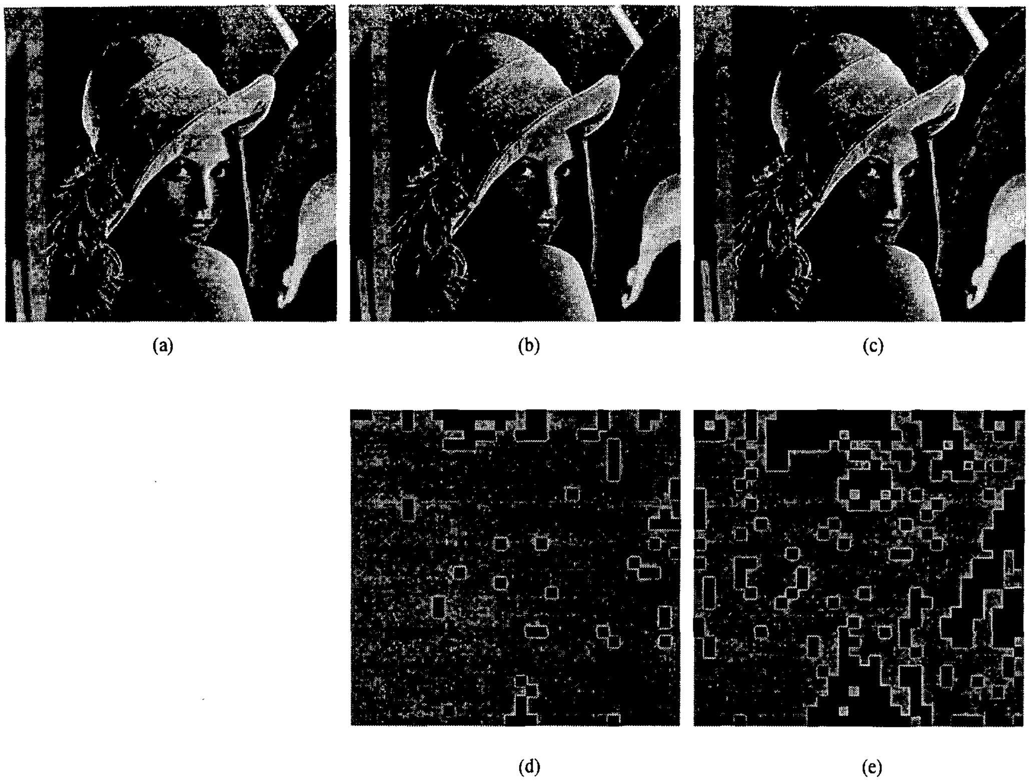

Figure 2. Base color selection. In the compressed image (a), Green color was selected as a base color in all subblocks. In (b), the base color is the most correlative color, in (c) the base color is the color that produces the best results. (d) and (e) indicate the base color in each sub-block of (b) and (c) images respectively.

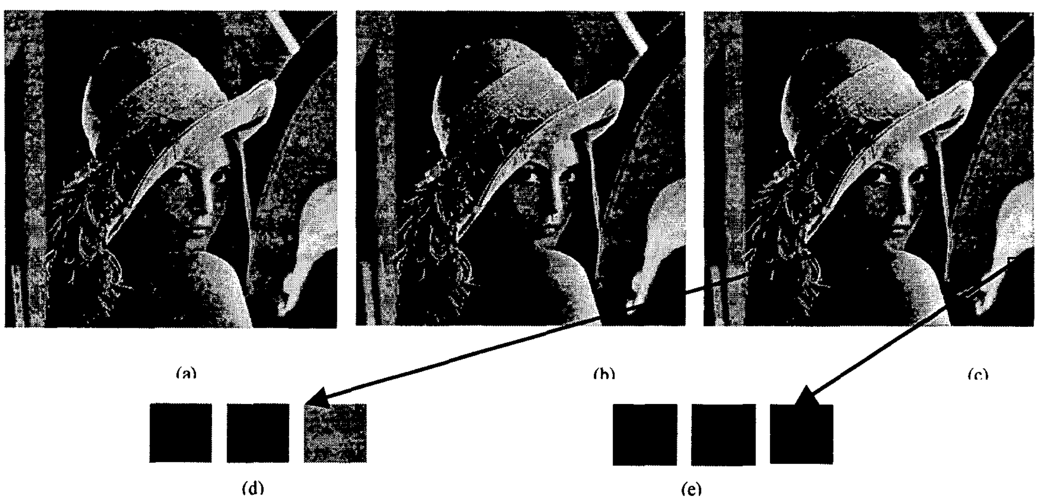

Figure 3. Results of the proposed technique. The original image (a) is compressed by the proposed color correlation method in (b), and using the JPEG algorithm in (c). The color information in both compressed image is coded at 0.06 bpp. Enlarged set of blocks (d) and (e) show color artifacts introduced by JPEG (right in each set) compared to the corresponding blocks of the original image (left) and of the proposed algorithm (middle).

most blocks, Huffman coding [3] is used to efficiently encode the index of the base colors. In addition, since the polynomial coefficients of adjacent blocks tend to be similar [6], the encoding of these coefficients is based on Delta modulation. Application of these techniques achieves 50% improvement in the compression rate of color information compared to the basic approach.

The quality of compressed images was evaluated both visually and by calculating the PSNR quality measure. In the compressed images, shown in Figure 3, the color information (second and third components for the proposed algorithm, and the IQ for JPEG) is compressed as indicated at 0.06 bit/pixel.

Both techniques attain good results. In a printed version of the images, the compression does not introduce visual artifacts. PSNR indicates similar compression quality for both techniques.

Thorough analysis of the compressed images however shows that the proposed algorithm better preserves color information than JPEG, as illustrated in Figures 3d and 3e. Our conclusion is that the proposed approach provides more accurate results than JPEG for a similar compression rate.

5. Summary

A color representation technique that takes advantage of high intercolor correlation of RGB components in natural images has been developed. Unlike most methods, the proposed technique utilizes the correlation between color bands instead of decorrelating them. Indeed, if one can efficiently decorrelate the information so that there is very low correlation between the luminance (Y) and chrominance (IQ or UV), both methods should yield similar results. As can be concluded, however, those techniques that are based on the YIQ components, do not achieve this goal to the full extent since YIQ are not completely decorrelated. In fact it is easy to recognize most images by looking just at the I or Q components (Figure 4). Instead of decorrelating the components, the current approach proposes to use this correlation. This high correlation implicitly suggests functional relation between the components, and the proposed method uses this property instead of minimizing it.

We have shown that the proposed method is superior in preserving color information. Since the correlation is efficiently utilized here compared to other compression techniques such as JPEG, it indeed provides better results than the latter. Our conclusion is that in color representation, a correlation-based approach is superior to the traditional decorrelation methods.

Figure 4. As can be seen here, the decorrelated In-phase (I, left) and the Quadrature (Q, right) components still have high correlation to the original image of 'Lena'.

6. References

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