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Optimized Colorization based Coding on Separated Geometry and Texture

Bhagya D

Abstract— Due to the rapid growth of multimedia revolution, there is an increasing demand for better image compression techniques. Colorization based coding is a class of image compression technique that uses colorization methods. In the colorization approach, the color values of an image are obtained from a few pixels having color information. The color information of these pixels is propagated to neighboring pixels by colorization methods making the whole image colorized. The encoder chooses the pixels required for the colorization process, which are called RP (Representative Pixels), and maintains the color information only for the RP. Then, the decoder restores the color information for the remining pixels using colorization methods. The main issue in colorization based coding is how to extract the RP such that the compression rate and the quality of restored image becomes good. High visual quality and compression rate can be achieved by formulating RP selection problem into an optimization problem, that is an L1 minimization problem. Another issue in colorization based coding is that the decoded chrominance lose the local oscillation that the original images had. By performing separate encoding for geometry and texture, the visual quality of the reconstructed image can be improved. In this method, the geometry and texture of an image are separated using total variation regularization .The texture components are compressed into coefficients that represent the correlation between luminance and chrominance, and the geometry components are compressed by formulating the RP selection problem into an L1 minimization problem. Thus the image can be compressed with reconstructed image having high visual quality.

Index Terms— Colorization, Geometry, JPEG Compression, local oscillation, L1 minimization , Representative Pixels, Texture, Total Variation Regularization.

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1 Introduction

IN the last decade, we have been witnessing a revolution including ever-growing Internet, explosive development of mobile communication etc. Due to the rapid growth of multimedia revolution, there is an increasing demand for better image compression techniques. A common characteristic of most of the images is that the neighboring pixels are correlated and therefore contain redundant information. The objective of image compression is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form.

Colorization based coding is a class of image compression technique that uses colorization methods. In the colorization approach, the color values of an image are obtained from a few pixels having color information. The color information of these pixels is propagated to neighboring pixels making the whole image colorized.

Colorization based coding utilizes the fact that the required number of pixels having color information is small. The encoder choose the pixels required for the colorization process,which are called RP(Representative Pixels), and maintains the color information only for the RP.Then, the decoder restores the color information for the remaining pixels using colorization methods.

The main issue in colorization based coding is how to extract the RP such that the compression rate and the quality of the restored image become good. Another issue is how to restore the chrominance components without losing the local oscillation that the original images had. The objective of this thesis is to implement a colorization based compression algo rithm that results in high visual quality and compression rate.

The remainder of the thesis is organized as follows.Section 2 describes similar existing techniques. Section 3 describes the problem and the methodology for the proposed method is explained in Section 4. The experimental results are presented in Section 5. Finally, some concluding remarks and future scope of the proposed method are mentioned in Section 6.

2 Related Literature

In recent years, several algorithms for colorization based coding have been proposed.Colorization based coding uses the color information of a few selected pixels known as representative pixels (RP) for adding color to the whole gray image. This method utilizes the fact that the information amount for representing positions and color values of these pixels is small. In Colorization-based coding, an encoder extracts RP from an original color image and transmits RP and all luminance components (compressed by conventional encoder) to a decoder.

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- *Bhagya D is currently pursuing masters degree program in communication engineering in Federal Institute of Science and Technology, India . E-mail: bhagya.divakaran@mail.com*

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Then, the decoder restores a color image by colorization. The key step in any colorization-based coding is automatic RP extraction .The choice of the extraction method determines the performance of the colorization-based coding method. Generally, the best among several sets of RP achieving the same decode quality is the one containing the smallest number of pixels. That is the RP should not include redundant pixels that contribute little to the quality of the decoded color components. Following are the different existing colorization based coding algorithms.

2.1 Cheng's method

In 2007, Cheng et al. [2] proposed an intuitive scheme for lossy color image compression. This algorithm used the color information from a few representative pixels to learn a model which predicts color on the rest of the pixels. The representative pixels and the image in grayscale suffice are stored to recover the original image. This algorithm uses a graph-based inductive semi-supervised learning module for colorization, and a simple active learning strategy to choose the representative pixels.

Cheng et al.'s method adds new pixels to the RP by iterative selection starting from randomly selected initial RP. However, if the initial RP already have some redundancy, there is no procedure for reducing it.

2.2 He's method

In 2009, He et al. [3] proposed a novel active learning algorithm, called Graph Regularized Experimental Design (GRED), which shares the same principle of the semi-supervised learning algorithm used for colorization, to select the representative pixels. Thus, the active and semi-supervised learning is unified into a single framework for RP selection and colorization.

He et al.'s method selects candidate RP as the first step. Then, RP are extracted from the candidate pixels by sequential selection. However, if the candidate pixels do not initially include the pixels required for suppressing coding error, such pixels cannot be extracted at any stage by this method. Moreover, He et al.'s method does not use the color components of the original image to extract RP. Because of this, this method may not extract the required pixels for RP in many cases.

2.3 Ono's method

In 2010, Ono et al. [4] proposed a new colorization-based coding method that overcomes the limitations of Cheng's and He's algorithms. This method first simply segments the original image into squares and extracts RP from each square as initial RP. Then, it reduces the redundant RP in the initial RP by focusing on characteristics of colorization bases of decoded color components which is determined by the positions of the RP and luminance components. Moreover, by using the determined colorization bases and original color components, this method extracts RP from pixels that were not extracted as initial RP.

Ono et al's method can achieve four times better compression rate than previous methods for same image quality. But the selected pixels are not optimum and have visual artifacts.

2.4 Ryu's method

In 2013, Ryu et al. [5] proposed a mean shift segmentation based RP selection method. The modes obtained by mean shift segmentation are used as the RP. Thus RP have high effect on the regions that approximately correspond to the regions clustered by the mean shift segmentation. The mean shift procedure has to be repeated several times until an almost optimal set of required RP are obtained.

3 Problem Description

The main issue in colorization based coding is how to extract the RP set so that the compression rate and the quality of the restored color image become good. Several methods have been proposed to this end as explained in the previous chapter. All these methods take an iterative approach. In these methods, first, a random set of RP is selected. Then, a color image is reconstructed using the RP set, and the quality of the reconstructed color image is evaluated by comparing it with the original color image.

Additive RP are extracted from regions where the quality does not satisfy a certain criterion using RP extraction methods, while redundant RP are reduced using RP reduction methods. However, the set of RP may still contain redundant pixels or some required pixels may be missing. Here lies the significance of optimization.

Optimized colorization based compression is a colorization based coding algorithm that selects optimum representative pixels. The proposed method achieves this by formulating the RP selection problem into an optimization problem, that is, an L1 minimization problem. The selection of the RP can be made optimal with respect to the given colorization matrix in the sense that the difference error between the original color image and the reconstructed color image becomes minimum. Moreover, the number of pixels in the RP set can be minimized by the L1 minimization.

Although the conventional method of colorization based coding outperforms JPEG in terms of visual quality, the decoded chrominance components lose the local oscillation that the original images had. Since the local oscillations represent the textures and shadows of materials, the loss of such oscillations leads to considerable degradation of subjective quality. A large no of color assignations is required to restore these oscillations precisely. These oscillating patterns of an image are known as texture of the image whereas the image contrasted shapes of image is known as geometry. Conventional methods largely neglect the effect of texture. By performing separate encoding for geometry and texture, the visual quality of the reconstructed image can be improved.

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4 METHODOLOY

The main steps involved in encoder and decoder of optimized colorization based compression on separated geometry and texture can be summarized as shown in Fig.1.

The main steps in optimized colorization based compression with geometry – texture separation are as follows: First the image is divided into luminance(Y) and chrominance components(Cb and Cr).Then for each component Y,Cb and Cr , geometry and texture are separated using total variation regularization to get geometry components Y_g,C_{bg} and C_{rg} and texture components Y_t,C_{bt},C_{rt} . The luminance component is compressed using JPEG compression technique. Mean shift segmentation is performed on the luminance of geometry, using which colorization matrix is constructed. Each column of colorization matrix corresponds to each segmented region and each row corresponds to each pixel of the image in raster scan order. If i^{th} pixel is present in j^{th} segmented region, then value of C at position (i , j) is set as one and otherwise as zero.

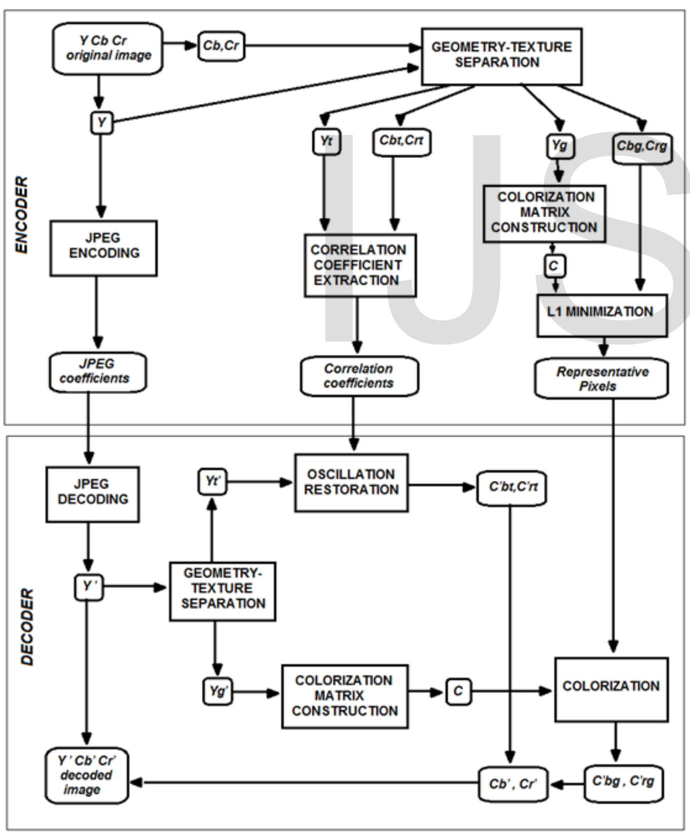

Fig.1.Overall block diagram of proposed method

Once the colorization matrix is constructed, next step is to extract RP set. In this method RP extraction problem is considered as a L1 minimization problem. Let u be a Nx1 column vector whose elements are the original color values of pixels in the image in raster-scan order, where, N is the number of pixels in the image. C is a NxM matrix, where M < N is the number of segmented regions obtained after mean shift segmentation. Our objective is to derive a RP set matrix x of size Mx1, such that u= Cx. Using, Orthogonal Matching Pursuit, representative pixels x_{cb} and x_{cr} are extracted for color coding of geometry.

For color coding of texture part, correlation coefficients a_{cb} and a_{cr} are extracted. The luminance and chrominance of texture component correlate and most chrominance changes are accompanied by luminance changes. Therefore each oscillation of the components in a local region has a similar shape and positive or negative correlation.

The relationship between luminance and chrominance of texture components can be represented as a corresponding linear function. Let K be the number of clusters obtained by mean shift segmenting the luminance of texture (Yt). Then color component of each pixel in a cluster can be represented as a linear function, $C_{bt}=Y_t\, a_{cb}$ and $C_{rt}=Y_t\, a_{cr}$..By sending two correlation coefficients a_{cb} and a_{cr} for each cluster, C_{bt} and C_{rt} can be reconstructed using luminance Y_t.

All the encoded coefficients (x_{cb} and x_{cr} , a_{cb} and a_{cr} , JPEG coefficients) are concatenated and sent to decoder.

Fig.2.a) Original image b) Reconstructed image

In the decoder, the JPEG coefficients are used to reconstruct the luminance(Y_t).The reconstructed luminance is divided into geometry(Y_g) and texture(Y_t).Colorization matrix C is constructed by mean shift segmenting the geometry part of luminance(Y_g) .Using C and RP set x_{cb} and x_{cr} geometry part of chrominance values (C_{bg} and C_{rg}) are reconstructed. Using texture part of luminance (Y_t) and correlation coefficients (a_{cb} and a_{cr}), texture part of chrominance (C_{bt},C_{rt}) are reconstructed. All components of geometry and texture are combined to restore the image.

5 RESULTS

The proposed scheme was applied on several images. The compression performance and visual quality was evaluated using compression gain and PSNR. Fig.2. shows the original and reconstructed image of Pepper. This can be achieved with a PSNR of 80.6605 dB and a compression gain of 76.1589%.

The results show that the compression gain can be significantly improved using the proposed method. The image results show better visual quality for the proposed method. Compared to other methods, this method leaves no area without being colorized whereas the result of other methods show false color assignation in several areas.

The optimized colorization based compression without geometry-texture separation is mentioned as proposed method and optimized colorization based compression with geometry-texture separation is mentioned as proposed method2 in the literature.

Fig.3 compares the local oscillations of chrominance component of reconstructed image for various methods. Black line shows local oscillation of Y component of original image. Red line shows local oscillation of Cb component of original image. Green line shows local oscillation of Cb component of reconstructed image by JPEG compression method. The local oscillation of Cb component of reconstructed image by proposed method and proposed method1 are represented by magenta and blue lines respectively. The lines represent the values extracted from the image 'Pepper', horizontal coordinate x Ɛ [1,512] and fixed vertical coordinate y=250.

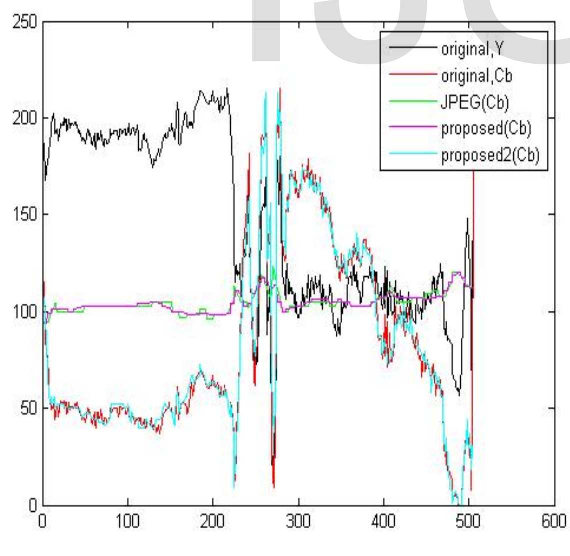

Fig.3.Oscillation Restoration Characteristics

Each oscillation of the original Y and Cb components in a local region has similar shape and positive or negative correlation. This oscillation of chrominance component is restored correctly in proposed method2. JPEG compression and proposed method smoothed the local oscillation.

Thus it is proved that the Optimized Colorization based Compression with Geometry-Texture Separation outperforms JPEG compression and Optimized Colorization based Compression without Geometry-Texture Separation in terms of oscillation restoration.

6 Conclusion

An Optimized Colorization Based Compression on Separated Geometry and Texture was implemented and analyzed. In this method, the geometry and texture of an image are separated using total variation regularization. The texture components are compressed into coefficients that represent the correlation between luminance and chrominance, and the geometry components are compressed by formulating the RP selection problem into an L1 minimization problem.

The compression performance and visual quality was evaluated using compression gain and PSNR. Using this scheme, the compression gain becomes high and the reconstructed image has good visual quality. By formulating the RP selection problem into an L1 minimization problem, the algorithm becomes optimum. Also, due to separate texture coding, the oscillation of original image is restored.
The speed of execution of proposed algorithm is slow. The method can be improved further by increasing the speed of algorithm. Also the proposed scheme can be extended from still images to video too.

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