Efficient Segmentation Techniques for Optimized Colorization based Compression

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Abstract- *We are proposing a new scheme for the colour image compression which uses the colour data from a couple of representative pixels to train a model that predicts colour of the remaining of the pixels. By storing the representative pixels, the image in grayscale is suffice to restore the first image. In this thesis, the colorization coding problem has been resolved using L1 norm minimisation sparse recovery algorithms (OMP). From the encoder, only a few representative pixels for the chrominance are sent together with brightness part of image to the decoder where the chrominance values for all the pixels are reconstructed by colorization technique. The main problem in colorization coding technique is to extract the RP efficiently to recreate the chrominance data of all the pixels for obtaining an excellent quality color image. In existing technique, the colorization matrix is created using the mean shift segmentation of brightness channel of the image. The C matrix extracts RP set by solving OMP. We proposes 2 additional kinds of segmentation schemes, multi scale k-means and multi scale super pixel. The quality of reconstructed image has been evaluated using the parameters - file size, MSE, PSNR and SSIM. Experiments shows that the proposed methods produce far better results, both qualitatively and quantitatively compared to existing strategies. Our methods also outperform standard colorization coding techniques as well as the JPEG standard. Also our proposed scheme is almost equally efficient compared to JPEG2000, in terms of the compression and also the quality of the retrieved colour image.*

I. INTRODUCTION

The unbelievable growth of the web, as witnessed by the recognition of Google, YouTube, Facebook and Whatsapp has tremendously redoubled the quantity of pictures and flicks out there for transfer. Since a lot of visual information is being transfered across the network, there arises an increasing need for higher compression strategies which can scale back network traffic and that conjointly helps in the effective utilization of bandwidth. Typical compression algorithms for pictures operate in the spectral domain and use subtle methods like DWT.

Now a days, a brand new compression method for colour images that relies on the utilization of colorization strategies [1]-[4] has been projected. Till now, many colorization methods are planned to colourize gray scale images using solely some representative pixels decided by the user [5]. Automatically extracting the representative pixels is the main objective in colorization based compression. The chrominance elements are transmitted to the decoder just for the RP set in conjunction with the luminance channel that is compressed by standard compression methods. So the decoder restores the colour data for the remaining pixels.

The main problem in colorization based coding is the way to extract the RP such that the compression rate and also the quality of the rebuilt colour pictures become sensible. Many strategies [1]-[4] are planned to the present end. All the strategies take an iterative approach. In all these strategies, first, a arbitrary set of RP is chosen. Then, a colour image is recreated using that RP, and also the quality is measured by comparing it with the original image. More RPs are extracted using RP extraction strategies, whereas redundant RP are removed using RP reduction strategies. However, RP set may contain redundant pixels or some needed pixels could be absent. This system proposes a new method to create the colorization matrix, which is incorporated with RP extraction technique to produce a prime quality retrieved colour image.

Conventional compression techniques for pictures operates in spectral domain, and use subtle methods like DWT. The conventional compression techniques are not so efficient and it needs complex coding. Now a days, a brand new compression technique for color pictures that is predicated on the employment of colorization strategies has been projected.

It will be shown by experimentation that the projected method compresses the colour image with greater compression rate than the traditional JPEG standard as well as alternative colorization coding strategies, and is almost equally efficient to the JPEG2000 even while not using complicated coding techniques.

The aim of this paper is to extract the RP expeditiously, in order to extend the compression rate and therefore the quality of the retrieved color image. The memory demand of the tactic will increase with the increase in size of segments and also the size of the colorization matrix. Therefore better segmentation techniques got to be used which can be scale back colorization matrix size and also extracts optimum set of RP.

II. PREVIOUS WORKS IN COLORIZATION

Colorization is an approach that adds colour elements to gray scale pictures. To grasp the proposed technique, three major connected works needs to be described.

A. Color Coding for Images

An overview of typical color image cryptography strategies is displayed in figure. In the encoder, original pictures are transformed from the RGB colour space to the YCbCr colour space. The human optical system is highly sensitive to changes in brightness compared to chrominance. To decrease the quantity of info, using this property, chrominance components (Cb, Cr) are usually sampled. Sampled chrominance and luminance are transformed into the spectral domain, and then quantized and encoded. In the decoder, inverse processes are used to reconstruct the pictures. Linear interpolation strategies are used to interpolate the sampled chrominance. Thus the decoded chrominance elements blur close to the edges.

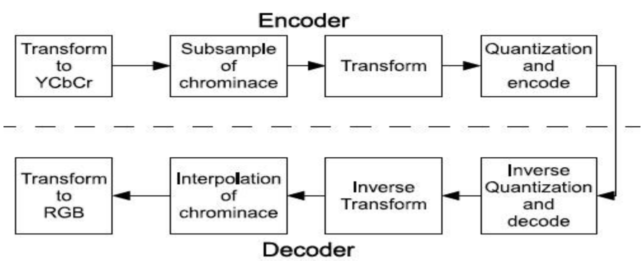

Fig. 1. Conventional colour coding method for images

B. Colorization Technique - Levin et al

Levin et al [5] proposes a colorization algorithmic rule that reconstructs the colours using the colour data for a few representative pixels and also the gray image that contains the brightness data. ie, using the YCbCr colour coordinate system, the colorization technique recreates all the Cb and Cr elements using the luminance element Y and also the Cb and Cr data for a few RP. The luminance vector is denoted as y and the solution vectoris denoted as u which contains the colour elements to be recreated within the decoder, and x is the vector that contains the colour values solely at the positions of the RP set, and zeros are placed at the remaining positions. The cost function outlined in this technique is,

$$J(u) = jjxAujj \quad (1)$$

that has got to be decreased with relation to u.

Fig. 2. Colorization - Levin's et al. (a) Gray scale image with colour scribbles (b)Colourised image

C. Existing Method

In the existing system [7], the RP selection is formulated as an L1 minimization optimization problem. The choice of the RP is less with reference to the generated colorization matrix. The difference error between the first color image with the retrieved color image becomes very small with respect to the L2 norm error. Through L1 minimization the pixels within the RP is decreased. The most effective set of RP is obtained through single minimization step and doesn't want any further refinement.

Colorization of a picture is done by segmenting the image into regions and assigning a color to each of these regions. Mean shift segmentation is used in existing system. For mean shift segmentation, there are two totally different parameters - photometric distance and spatial distance. Thus, mean shift segmentation we will produce segments of various spatial and photometric characteristics. Multi-scale Segmentation is used because single scale may lacks some of the Cb and Cr components.

1) Mean shift segmentation: Mean shift is the procedure for finding the maxima of a density function. It's helpful for detection the modes of this density. This can be a repetitive methodology, and that we begin with an initial estimate. Mean shift cluster algorithms retain a collection of data points of similar size as the input file set. At the beginning, this set is derived from the input set. Later, this set is iteratively substituted by the mean value of these points within the set that are at intervals of a given distance from that point.

III. PROPOSED METHOD

Recent compression strategies attempt to compress the picture without changing the image from its spatial domain illustration to spectral domain illustration. Completely different compression techniques are projected however these techniques either need extraction of giant variety of RPs that depletes the compression ratio or obtains the RPs in an iterative manner that could be a time consuming method.

Research shows that the prevailing methodology exceeds the rest of the colorization cryptography strategies to a large extent in qualitative as well as quantitative measures. The memory demand of the strategy will increase with increase in the size of the segments and hence the size of the colorization matrix. Thus an effective segmentation approach could also be employed in future which can be reducing the size of the colorization matrix and also extracts best set of RP. Thus we proposed two new segmentation techniques to reduce the size of colorization matrix and to produce higher compression by holding the quality. Our proposed method 1 uses multiscale k-means segmentation for generating the colorization matrix and proposed method 2 make use of multiscale super pixel segmentation for the same. 2

IV. PROPOSED METHOD 1

Segmentation is a key tool used to reduce the size of colorization matrix and to extracts optimal RP set. In this method, multi scale k-means clustering is used for segmentation.

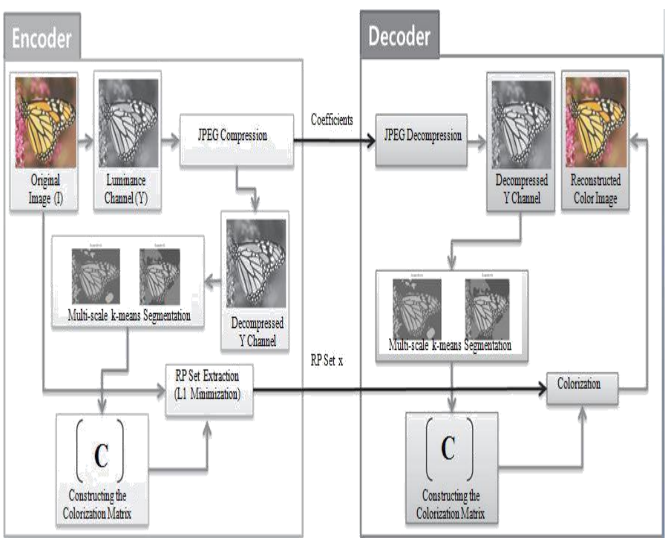

Fig. 3. Proposed Method 1

A. System Design

The planned methodology 1 includes the encoding and de-coding methods. Within the encoder, the initial color image is first split into its chrominance channel and brightness channel. The brightness channel is compressed through typical JPEG compression technique, and its distinct Fourier coefficients are transmitted to the decoder. In the encoder, the colorization matrix C is built through multi-scale k-means segmentation of the decoded luminance channel. Exploiting this C matrix and also the chrominance elements derived from the original color image, the required RP is taken by solving a minimization problem. This RP set is transmitted towards the decoder. There the C matrix is recreated from the brightness channel. Later, by executing the colorization using the C matrix and the RP set, the color image is retrieved.

B. RP Set Extraction

Colorization based compression technique proposes a repetious sparse cryptography technique for the deducing the RP set. The choice of RP set will be developed into sparse recovery optimization problem. The acceptable RP values are calculated by resolving the L0 minimization problem and L1 norm minimization sparse recovery algorithms(OMP) selected the RP values in the encoder in such a way that it removes the amount of non-zero elements from the colorization matrix. The answer will be obtained provided that colorization matrix satisfies the Restricted Isometric Property (RIP). For satisfying the RIP, C matrix is multiplied with a random Gaussian matrix. Observations reveals that this technique selects optimum set of RP and optimum colorization matrix. The main problem in colorization coding is to deduce an honest RP set from the first color image. Colorization of a picture is done by segmenting an image into different regions and assigning a color to each of these regions. In the multi scale segmentation to form the colorization matrix, we tend to use multi scale k-means segmentation.

1) k-means Segmentation: k-means segmentation is a technique of vector quantization in signal processing which is widespread for cluster analysis in data processing. The main objective of k-means clustering is to distribute n observation vectors into k clusters during which every observation belongs to the cluster with the closest mean.

C. L1 Minimization Optimization

The colorization technique suggested in [5], extracts the RP set which is denoted by the vector x. The color vector u is calculated from familiar RP set vector x in the decoder using,

$$u = A^{-1}x \quad (2)$$

where A is the RP extraction matrix. This RP set is selected in such a way that it reduces the distinction between original image and retrieved one. The method of selecting RP set is carried out through iterations until minimum difference is obtained. In every iteration, the matrix A is built that will increase computation cost. The redundant RPs are reduced and also the only needed ones are extracted iteratively. To simplify this algorithm, optimization techniques could also be adopted. It can be formulated as,

$$|x|_{0}, \text{ s.t. } b = Ax \quad (3)$$

Since the answer is non-deterministic polynomial-time hard, so L1 minimization technique could also be applied as,

$$|x|_1, \text{s.t.}\, b = Ax \quad (4)$$

The solution of equation can be deduced if A satisfies Restricted Isometric Property. To implement L1 minimization, Orthogonal Matching Pursuit is used.

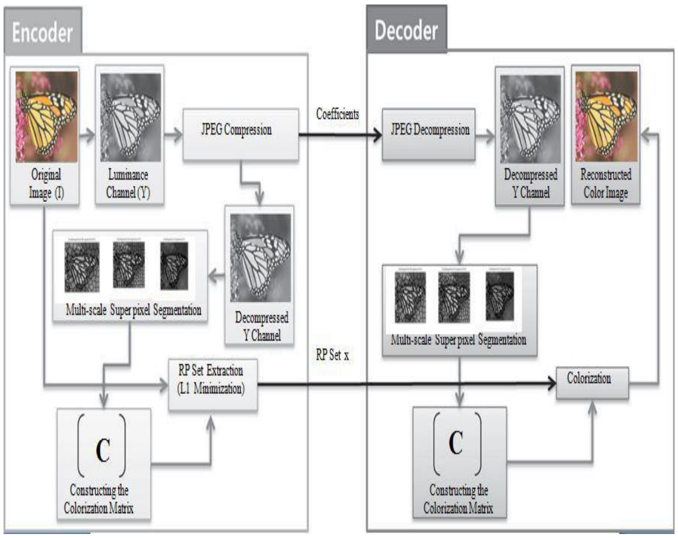

Fig. 4. Proposed Method 2

1) Orthogonal Matching Pursuit: Matching pursuit is a sparse approximation algorithmic rule that involves finding the best matching projections of multidimensional information onto the span of an over-complete dictionary D. The basic idea is to approximately represent a signal f from Hilbert space Has a weighted sum of finitely many functions g ɼn(called atoms) taken from D: An approximation with N atoms has the form

$$f(t) \approx F_N(t) := \sum_{n=1}^{N} a_n g_{ɼn}(t)$$

where αn is the scalar weighting factor for the atom gɼn Є D Instead, matching pursuit chooses the atoms one at a time so as to maximally (greedily) scale back the approximation error. This can be achieved by finding the atom which has the largest dot product with the signal, subtracting from the signal an approximation that uses solely that one atom, and repeating the method till the signal is satisfactorily decomposed, i.e., the norm of the residual is little, wherever the residual after calculating ɼN and αN is denoted by,

$$R_{N+1} = f - F_N$$

If Rn converges quickly to zero, then only a few atoms are needed to get a good approximation to f. Such sparse representations are desirable for signal compression.

In Orthogonal Matching Pursuit, the most distinction from the matching pursuit is that after each step, all the coefficients extracted to date are updated, by finding the orthogonal projection of the signal onto the set of atoms designated to date. This could provide better results than normal MP, however needs a lot of computation.

V. PROPOSED METHOD 2

The proposed method is modified a little in the segmentation part. Instead of k-mean clustering, super pixel segmentation is performed in the proposed method 2. Super pixel segmentation again reduces the size of colorization matrix compared to k-means clustering.

A. System Design

The planned methodology 2 includes the encoding and decoding methods. In the encoder, the original color image is first converted into the YCbCr color space. Then the luminance channel Y is compressed using the conventional JPEG. The coefficients are transmitted to the decoder. At the same time in the encoder, the compressed luminance channel is decompressed for segmentation. The multi scale segmentation of the decoded Y channel results in the generation of the colorization matrix C. The C matrix along with the Cb, Cr components in the original image will produce the RP set through the L1 minimization. The RP set x and coefficients are together transmitted to the decoder. In the decoder, the coefficients are decoded to form the decoded luminance channel. This is multi scale segmented to recreate the colorization matrix C at the decoder. The C matrix is combined with the RP set x to colorize the Y channel and thus to reconstruct the original color image.

1) Super pixel Segmentation: A Super pixel may be a plane figure a part of a digital image, larger than a traditional pixel, that's rendered within the same color and brightness. Super pixels are getting more and more well-liked to be used in computer vision applications. Super pixels offer a convenient unsophisticated from that to calculate native image characteristics. They capture redundancy within the image and greatly reduce the complexity of succeeding image processing tasks.

Simple Linear Iterative Clustering (SLIC) algorithmic program performs a neighborhood clustering of pixels. This is quick, simple to use, and produce high quality segmentations. SLIC may be a straightforward and economical technique to

TABLE I

IMAGES USED FOR OUR EXPERIMENT

Image	Size(pixels)	File format
Butterfly	294x250	.bmp
Lena	128x128	.bmp
Pepper	128x128	.bmp
Barbara	128x128	.jpg
Baboon	128x128	.png
Cat	170x128	.jpg

decompose a picture in visually consistent regions. In super pixel segmentation every pixel is related to a feature vector,

$$\varphi(x,y) = \begin{matrix} \lambda x \\ \lambda y \\ I(x,y) \end{matrix}$$

The coefficient balances the appearance and spatial components of the feature vectors.

SLIC comprises of two parameters: the regionSize, nominal size of the super pixels and the regularizer, strength of the spatial regularization. The image is initially divided into region Size. The parameter, regularizer sets the trade-off between clustering appearance and spatial regularization. This can be obtained by setting,

$$\lambda = \frac{regularizer}{regionSize}$$

in the definition of the feature ψ(x; y).

VI. RESULTS AND DISCUSSION

The efficiency of the proposed methods are evaluated using 6 images of different size and different file format such as JPEG,PNG and BMP .The experiments were carried out on a Windows 10 PC with the configuration of Intel Core i5 Processor;3.20 GHz and 8 GB RAM. All algorithms were implemented using MATLAB 8.3.0 (R2014a).

Our experiments are carried out using 6 different images. Among that only one image analysis is explained in detail in this report. The existing system and two proposed methods are implemented and their detailed analysis is made using the selected parameters. The effect of compression is measured both qualitatively and quantitatively.The proposed methods were compared with the traditional JPEG and the JPEG2000 standards.The standard JPEG/JPEG2000 encoders in MAT-LAB are used for the comparitive study. The different images used for our experiments are:

For the sake of simplicity, the ’Butterfly’ image is explained in this report. In the encoder, the original image is first converted into the YCbCr colour space. Then the luminance channel Y is compressed using the conventional JPEG. The coefficients are transmitted to the decoder. Simultaneously in the encoder, the compressed luminance channel is decom-pressed for segmentation. The multi-scale segmentation of the

decoded Y channel results in the generation of the colorization matrix C. The C matrix along with the Cb, Cr components in the original image will produce the RP set through the L1 minimization. The RP set x and coefficients are together transmitted to the decoder.

In the decoder, the coefficients are decoded to form the decoded brightness channel. This is multi scale segmented to recreate the colorization matrix C at the decoder. The C matrix is combined with the RP set x to colorize the Y channel and thus to reconstruct the original colour image.

VII. OBSERVATIONS

The original colour image ’Butterfly’ (294x250), is converted into YCbCr color space and the luminance channel is compressed and decompressed using conventional JPEG.

Fig. 5. Original image Butterfly 294x250

Fig. 6. Luminance channel Y

Fig. 7. Decoded Y Channel

A. Segmentation Techniques

Different segmentation techniques are implemented for ex-isting and proposed methods.

1) Existing method: The existing method uses the multi-scale mean shift segmentation for creating the colorization matrix C. Here, we carried out the mean shift with window sizes 128 and 64. Each scale possess many segments.

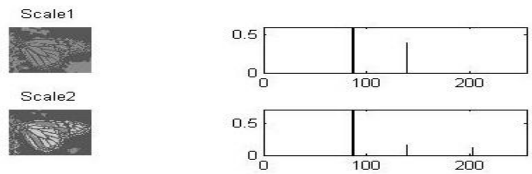

Fig. 8. Multiple scales of mean shift segmentation

Fig. 9. Segments generated through mean shift

2) Proposed method 1: The proposed method 1 introduces multi-scale k-means segmentation. The cluster size, K is chosen as 2 and 3 for two different scales.

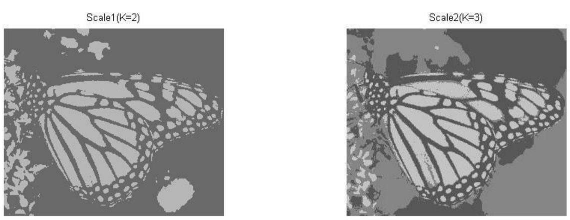

Fig. 10. k-means segmentation with 2 scales

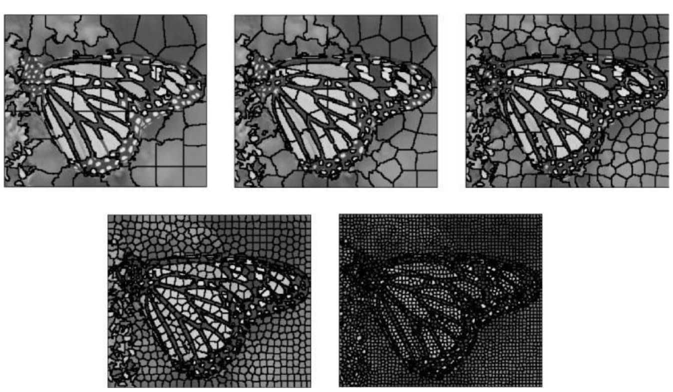

Fig. 11. Super pixel segmentation with 5 scales

3) Proposed Method 2: The distinguished feature of proposed method 2 is multi-scale super pixel segmentation

4) Output: Proposed 1 and proposed 2 methods produce better output compared with the existing method. The proposed method 2 is computationally fast to reconstruct the original image with sufficient quality and high compression rate.

VIII. COMPARISON OF RESULTS

The performances of the proposed methods are measured using the well known parameters MSE, PSNR and SSIM which were widely used to evaluate the quality of the image. They can be defined by the following equations:


Fig. 12. Original image Fig. 13. Existing output


Fig. 14. Proposed 1 Fig. 15. Proposed 2

PSNR for an image X and its degraded version Y is given by,

$$PSNR = 20log_{10}\left\{\frac{Max_X}{\sqrt{MSE}}\right\}$$

where, mean squared error (MSE) is given by,

$$MSE = \frac{1}{mn}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}||X(i,j) - Y(i,j)||^2$$

SSIM is a measure of likeness between two images. For two images X and Y, SSIM is given by,

$$\mathrm{SSIM(X;\ Y)} = \frac{(2\,\mu_x\,\mu_y + \mathrm{c1})(2\sigma_{xy} + \mathrm{c2})}{(\mu_x{}^2 + \mu_y{}^2 + C1)(\sigma_x{}^2 + \sigma_y{}^2 + C2)}$$

where, μ_x is the mean of X, μ_y is the mean of Y , $\sigma_x{}^2$ is the variance of X, $\sigma_y{}^2$ is the variance of Y , XY is the covariance of X and Y , c1 = (0.01L)2 and c2 = (0.03L)2 are variables for a dynamic range L of pixel values.

In this thesis, the proposed methods are compared with the existing system and also with the conventional compression standards, JPEG and JPEG 2000.The comparison is done both qualitatively and quantitatively. The efficiency of the projected schemes are analyzed using the parameters - file size, MSE, PSNR and SSIM.

The comparitive study of the existing methods and proposed methods with JPEG and JPEG 2000 is done by making the file size almost equal and measuring the MSE & PSNR values.

TABLE II
COMPARITIVE STUDY OF EXISTING SYSTEM WITH JPEG AND JPEG 2000

Method	FileSize(in KB)	MSE	PSNR(in dB)
JPEG	5.86	54.46	30.77
JPEG 2000	5.74	20	35.12
Existing System	5.67	48.54	31.27

TABLE III
COMPARITIVE STUDY OF PROPOSED METHOD 1 WITH JPEG AND JPEG 2000

Method	FileSize(in KB)	MSE	PSNR(in dB)
JPEG	6.25	47.43	31.37
JPEG 2000	5.92	18.33	35.5
Proposed 1	6.05	39.36	32.18

TABLE IV
COMPARITIVE STUDY OF PROPOSED METHOD 2 WITH JPEG AND JPEG 2000

Method	FileSize(in KB)	MSE	PSNR(in dB)
JPEG	5.09	70.81	29.63
JPEG 2000	4.98	27.42	33.75
Proposed 2	5.08	27.93	33.67

MSE and PSNR shows an inverse relation. The existing method and proposed method provides higher PSNR when compared to JPEG standard.ie, a high quality image can be reconstructed with decreased file size. The PSNR measures of the proposed methods are almost comparable with the JPEG 2000 too.

The proposed methods are also compared with the existing method by using the parameters - file size, MSE, PSNR and SSIM. For comparison we take a uniform JPEG encode quality of the luminance channel for all the three methods. Here for the ”Butterfly” image, it is taken as 60.

TABLE V
COMPARITIVE STUDY OF EXISTING METHOD WITH PROPOSED METHODS

Parameters	Existing	Proposed 1	Proposed 2
FileSize(in KB)	5.67	6.05	5.08
MSE	48.54	39.36	27.93
PSNR(in dB)	31.27	32.18	33.67
SSIM	0.9309	0.9479	0.9703

IX. CONCLUSION AND FUTURE WORK

Two novel methods have been proposed in colorization based coding technique. The proposed method 1 uses multi-scale k-means segmentation and proposed method 2 uses multi-scale super pixel segmentation. The proposed methods overcome the existing system in terms of file size, MSE, PSNR and SSIM. These methods also surpass the conventional JPEG and comparable with JPEG2000.The proposed method 2 reduces the computational time compared with the existing system. High quality image can be reproduced with decreased file size.

Future exploration could be concentrated on the memory constraint. For the smooth running of the algorithm, we use 8 GB RAM. The use of large memory still remains as a problem. Moreover, the computational cost cannot be reduced to a great extent. This can also be studied. The minimisation algorithm can be modified to reduce the size of the colorization matrix and also to enhance the computational efficiency. The proposed scheme can also be extended for colorizing the video frames.ie, the pixels of a single frame can be utilized to colour the adjacent video frames.

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