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YCbCr, YIQ and RGB Color Spaces with Haar, Cosine, Hartley and Slant Transforms for Grayscale Image Colorization using Thepade's Transform Error Vector Rotation Algorithms

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ABSTRACT

Hartley, Cosine, Slant and Haar Transforms for Grayscale Image Colorization Using Thepade's Transform Error Vector Rotation(TTEVR) Algorithms of Vector Quantization in YIQ, RGB and YCbCr color spaces are compared here for color pallet(codebook) size 32, 64, 128, 256 and 512. Here a color pallet is produced from reference(color) image from which color traits need to be taken using vector quantization using Thepade's transform error vector rotation algorithms in the first stage. Then colors are transferred to a target (grayscale) image using generated color pallet in the second stage. There exist no objective criteria for checking the performance of the colorization quality of proposed technique, here the grayscale version of original color image is recolored using proposed techniques and the mean squared error between original color image and recolored image is used as quality comparison criteria. The experimentation is done on 15 different images in RGB, YCbCr and YIQ color spaces for 5 different color pallet sizes. The proposed technique performs better in RGB color space. For RGB color space, the proposed technique using THEVR for color pallet size 512 gives better results, for YIQ color space, the proposed technique using TSlEVR for color pallet size 256 gives better results and for YCbCr color space, the proposed technique using THtEVR, TSlEVR, TCEVR for color pallet size 32 give better results.

Keywords: color pallet, THEVR, TCEVR, TSlEVR, THtEVR

INTRODUCTION

The process of colorization is a computer aided procedure that colors a monochrome image. In this process color traits are transferred to monochrome image. A grayscale image is a one dimensional image which carries intensity information.

A color image is a combination of Red, Green and Blue color components. It is easy to find grayscale version of a color image by taking pixel wise weighted average of individual color component values but to find colored version of grayscale image is a difficult process. To obtain the color component values for respective pixel wise grayscale values if only grayscale image is available becomes very complicated, as there can several combinations of color component values resulting into their weighted average as the same grayscale value[10]. This 'many to one mapping' problem is converted into 'one to one' probable mapping by taking group of pixels of color image along with their grayscale equivalents to generate color pallet. This color pallet based on collection of grayscale pixels of target grayscale image can be used for colorization. The paper put forwards use of Thepade's Transform Error Vector Rotation (TTEVR) algorithms for the color pallet generation with four assorted orthogonal transforms like Haar, Slant, Hartley, Cosine with help of RGB, YIQ and YCbCr color spaces.

Colorization of grayscale images enlightens visual appearance and provides more information than monochrome images. Colorization has many applications like vintage film colorization, old photo restoration, special effects, medical imaging, recolorization[5].

Various methods have been proposed for grayscale image colorization from scribbling to segmentation. Few methods of grayscale image colorization are discussed in literature survey.

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LITERATURE SURVEY

Grayscale image colorization techniques can be differentiated into local approach, intermediate approach and global approach. By taking group of pixels individually, the colorization work is done in local approach. In global approach the complete image is considered as a whole. Local and global approaches are combined in intermediate approach used in the intermediate approach.

Scribbling and swatches belong to local approach. Partial segmentation comes under intermediate approach. There are two methods in global approach colorization using VQ and pixel window. No manual work is required except selecting the source image in global approach [8][9]. Figure 1 shows classification of colorization approaches. A few methods of both the approaches are discussed here.

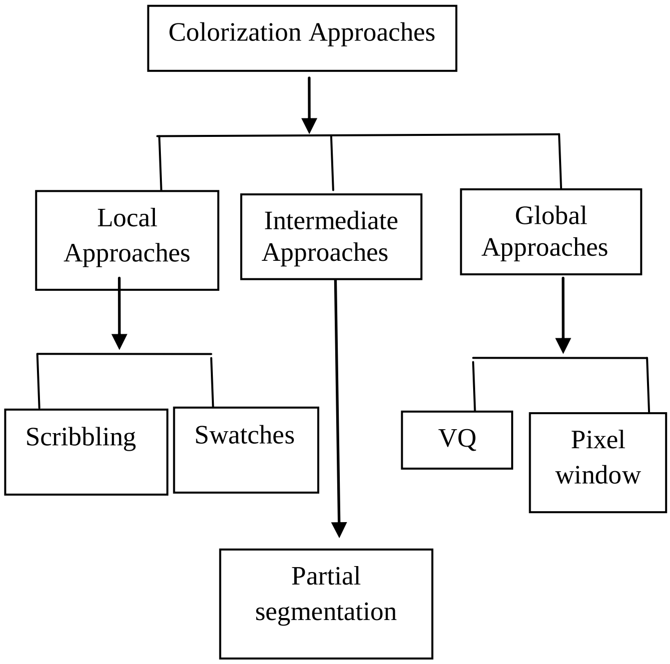

Figure1. *Classification of existing colorization approaches*

Levin et al.[12] has proposed a user assisted colorization method. In this method user is required to draw scribbles of colors in the interior of several regions. These constraints are formulated as a least squares optimization problem that automatically procreates the scribbled colors to produce a completely colorized image. But many complicated images need more amount of user drawn scribbles. And also the source image size is larger than the target image size that results into color pallet of varying sizes.

Welsh et al.[13] depict a technique for coloring a grayscale image by transferring colors from reference color image. They examined the luminance values in the neighborhood of each pixel in the target image and transfer the color from pixels with matching neighborhood in the reference image. This method has a drawback that the source image size is larger than the target image size that results into color pallet of varying sizes.

Reinhard et al.[14] employed lαβ color space which diminishes correlation between channels. The key idea of the paper is to put together the color transferring technique with texture synthesis techniques. But this approach breaks down when corresponding colors don't have corresponding luminance values.

The shortcoming of [13] and [12] is eliminated in [9]. This is an automatic approach of colorization. After finding the source color image for coloring a monochrome image, Conversion of the source color image from RGB to other color space is done. Then the image is broken into distinct blocks to form a training set. For obtaining the color pallet of needed size, standard VQ algorithm LBG(Linde-Buzo-Gray) is used[7]. In LBG algorithm, to form a training set, color(source) image is used. First codevector of this training set shows centroid. Create two vectors v1 and v2 by adding constant error to the codevector. Euclidean distances between all the training vectors and v1 and v2 are computed. This operation is reproduced for each cluster. This operation is repeated till we attain color pallet of needed size. Also break the grayscale (target) image into non overlapping blocks. The best match is found from the color pallet for each row of grayscale intensity with the help of Mean Squared Error. After attaining the best match for every row of grayscale (target) image, the colors are transferred to grayscale pixel from best searched pallet match. The idea is broadened using Thepade's Transfrom Error Vector Rotation algorithms with Cosine, Haar, Slant and Hartley for RGB, YIQ and YCbCr color spaces.

VECTOR QUANTIZATION

One of the lossy data compression techniques is vector quantization. To create a color pallet, VQ is used. To act as a mapping function, VQ is used that maps k-dimensional vector space to fixed set CB = {C1, C2, C3,…CN}. The set CB is named as codevectors and codevectors are Ci={ci1, ci2, ci3,…, cik}. A color pallet shows the entire image consists of a definite pixel pattern that shows color shades which is computed according to specific VQ algorithm. Here Thepade's error vector rotation (TCEVR, THEVR, TSlEVR, THtEVR) are used as specific VQ algorithms[11].

Thepade's Haar Error Vector Rotation (THEVR)

In THEVR, Haar transform proposed by Alfred Haar[17] is used. To give an example of a countable orthonormal scheme for the space of square-integral functions on the real line, Haar sequence is used. THEVR was developed for image compression[15]. The error matrix to be used here is given in equation (2).

$$E_{TH} = \begin{bmatrix} e_1 \\ e_2 \\ . \\ . \\ . \\ . \\ . \\ e_8 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \end{bmatrix} \quad (1)$$

Thepade's Cosine Error Vector Rotation (TCEVR)

Ahmed, Natrajan, and Rao [3] proposed discrete Cosine transform in 1974. In TCEVR, discrete Cosine transform is used. The discrete cosine transform belongs to a family of real –valued discrete sinusoidal unitary transforms. A discrete cosine transform involves a group of basis vectors that are sampled cosine functions. To transform a signal into elementary frequency components DCT is used. The discrete cosine transform is real and orthogonal. TCEVR was developed for image compression[16]. The error matrix to be used here is given in equation (1).

$$E_{TC} = \begin{bmatrix} e_1 \\ e_2 \\ . \\ . \\ . \\ . \\ . \\ e_8 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 \end{bmatrix} \quad (2)$$

Thepade's Slant Error Vector Rotation (TSLEVR)

In TSlEVR, Slant transform proposed by Enomoto and Shibata[4] is used. The slant transform has a different characteristic that it is a non sinusoidal orthogonal transform having sawtooth waveforms. It has the sequence property which diminishes monotonically in constant steps from maximum to minimum as well. TSlEVR was developed for image compression[2]. The error matrix to be used here is given in equation (3).

$$E_{TSL} = \begin{bmatrix} e_1 \\ e_2 \\ . \\ . \\ . \\ . \\ . \\ e_8 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \end{bmatrix} \quad (3)$$

Thepade's Hartley Error Vector Rotation (THTEVR)

In THtEVR, Hartley transform, a real valued unitary transform proposed by Bracewell[3] is used. THtEVR was developed for image compression[1]. The error matrix to be used here is given in equation (4).

$$E_{THT} = \begin{bmatrix} e_1 \\ e_2 \\ . \\ . \\ . \\ . \\ . \\ e_8 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 \end{bmatrix} \quad (4)$$

PROPOSED COLORIZATION TECHNIQUE

The proposed colorization techniques using THEVR, THtEVR, TCEVR & TSlEVR have two stages as color pallet generation and grayscale image colorization[11].

Generation of a Color Pallet Using Source Image

Step 1: The image is broken into non overlaaping blocks. Each block will change to vector to form training vector set.

Step 2: The centroid of this training vector is calculated by taking column wise mean.

Step 3: Produce Haar / Cosine / Slant / Hartley error vector e.

Step 4: Two matrices e1 and e2 are created by adding and subtracting error vector e_i from the code vector.

Step 5: Mean Squared error between all the training vectors belonging to this cluster is computed. Separate the clusters into two vectors v1 and v2.

Step 6: For the clusters attained in the above steps, centroid is calculated.

Step 7: i is incremented by one and step 4 to step 6 are reproduced for each codevector.

Step 8: Step 3 to Step 7 is reproduced till codebook of required size is obtained .i.e. our color pallet.

Colorization of Target Grayscale Image

Step 1: The target grayscale image is broken into distinct blocks.

Step 2: Steps 3 to 5 are reproduced for all distinct blocks of step 1.

Step 3: Alter a block into a vector of grayscale values.

Step 4: Mean Squared error (MSE) is computed between the grayscale part of color pallet vectors and this grayscale vector.

Step 5: Transfer the colors from the best matching color pallet vector to the grayscale vector based on minimum MSE value.

Step 6: To attain target color image, convert all grayscale vectors to the blocks with found color values.

RESULTS AND DISSCUSSION

The proposed techniques are implemented on Pentium IV, 2.10 GHz, 4 GB RAM using MATLAB. For testing purpose test bed of 15 training images of size 512 × 512 as shown in figure 2 is used.

Figure2. Training images for self recolorization

Table 1 shows average of MSE value between original and recolored images using proposed techniques using TCEVR, THEVR, THtEVR and TSlEVR for RGB, YIQ and YCbCr color spaces.

Figure 5 gives sample tested images in original and recolored forms for proposed grayscale image colorization techniques using TCEVR, THEVR, TSlEVR and THtEVR in RGB, YCbCr and YIQ color space. From figures 3 From the results, it is found that proposed technique using TCEVR performs the best in RGB and YCbCr color spaces but performs worse in YIQ color space. The proposed technique using TSlEVR performs the worst in RGB color space but performs better in YIQ and YCbCr color spaces. For YCbCr color space, proposed technique using THEVR performs the worst and it performs better in RGB and YIQ color spaces.The proposed technique using THtEVR performs worse in YIQ color space but performs better in RGB and YCbCr color spaces.

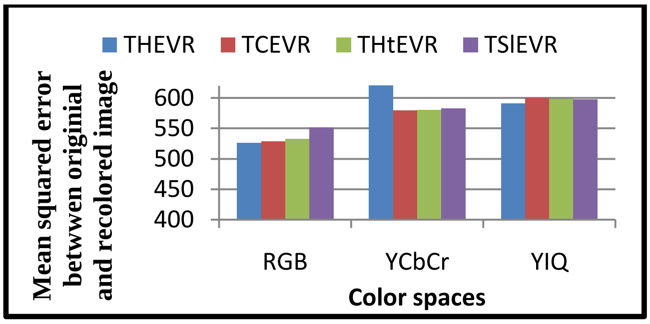

Figure3. *Comparison of proposed techniques with respect to average MSE between original and recolored image in RGB YIQ and YCbCr color space*

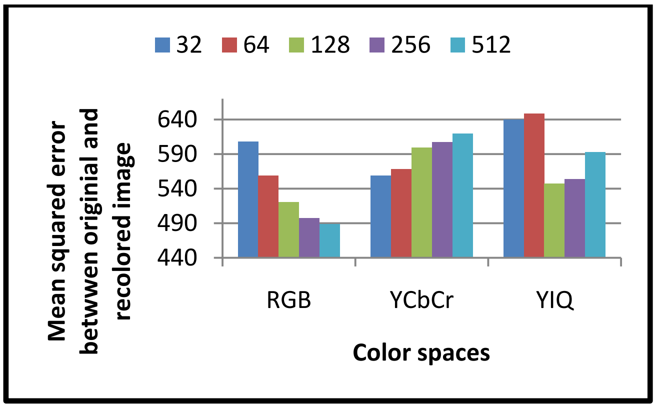

Figure4. *Comparison of color pallet sizes for proposed techniques with respect to average MSE between original and recolored image in RGB, YIQ and YCbCr color space*

Table I. *Average MSE of original and recolored images for proposed techniques using TCEVR, THEVR, THtEVR and TSlEVR on 15 color images from different categories of sizes 512 x 512 x 3 for color pallet size 512 in YCbCr, YIQ and RGB color spaces.*

Methods of Colorization	YCbCr	YIQ	RGB
Proposed technique using TSlEVR	615.04	**550.85**	513.55
Proposed technique using THtEVR	606.33	565.7	491.23
Proposed technique using THEVR	655.5	645.64	**460.52**
Proposed technique using TCEVR	**602.24**	575.65	475.81

From figure 4, it is observed from the results that lower color pallet sizes give better results using proposed techniques for YCbCr color space and higher color pallet sizes performs worse in YCbCr color space. Higher color pallet sizes give better results using proposed techniques for RGB color space and lower color pallet sizes performs worse in RGB color space . For YIQ color space, color pallet size 128 & 256 give less MSE value and color pallet size 32 & 64 give higher MSE value.

Figure 6 shows sample results of proposed techniques for colorization for different source and different target image for color pallet size 512.

Grayscale Image	Color Spaces used	Resultant image of TCEVR algorithm Color pallet size 512	Resultant image of THEVR algorithm Color pallet size 512	Resultant image of TSlEVR algorithm Color pallet size 512	Resultant image of THtEVR algorithm Color pallet size 512
	**RGB**	 **MSE = 229.58**	 **MSE = 224.31**	 **MSE = 228.85**	 **MSE = 231.67**
	YIQ	 **MSE = 243.11**	 **MSE = 212.27**	 **MSE = 250.86**	 **MSE = 256.24**
	YCbCr	 **MSE = 249.14**	 **MSE = 246.26**	 **MSE = 244.03**	 **MSE = 243.97**

Figure5. *A sample results of proposed colorization technique using TCEVR, THEVR, TSlEVR and THtEVR for recolorization in RGB,YIQ and YCbCr color spaces.*

Target Teddy Grayscale Image	Source Image	Proposed technique using TSlEVR	Proposed technique using THtEVR	Proposed technique using THEVR	Proposed technique using TCEVR
		 RGB	 RGB	 RGB	 RGB
		 YIQ	 YIQ	 YIQ	 YIQ
		 YCBCR	 YCBCR	 YCBCR	 YCBCR

Figure6. A sample result of proposed colorization technique using TSlEVR, THtEVR, THEVR and TCEVR for colorization

CONCLUSION

The performance of proposed techniques for RGB, YIQ and YCbCr color spaces using Thepade's transform error vector rotation algorithms are compared for transforms Cosine, Haar, Slant and Hartley. The proposed techniques outperforms in RGB color space. With higher color pallet sizes better performance is observed for RGB and YIQ color spaces. The proposed technique using THEVR performs better in RGB and YIQ color spaces. Lower color pallet sizes give better results using proposed techniques for YCbCr color space. The proposed technique using TCEVR, THtEVR and TSlEVR for YCbCr color space for color pallet size 32 give better results.

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