Colorization of Greyscale Images Using Kekre's Biorthogonal Color Spaces and Kekre's Fast Codebook Generation

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Abstract

There is no exact solution for colorization of greyscale images. The main focus of the techniques [24] is to minimise the human efforts needed in manually coloring the greyscale images. The human interaction is needed only to find a reference color image, then the job of transferring color traits from reference color image to greyscale image is done by techniques discussed in[1]. Here the colors from some source color image are picked up and squirted into the colored greyscale image. The color palette used in colorization technique discussed here is generated using the modified VQ codebook obtained by applying Kekre's Fast Codebook generation algorithm. The technique is tested using various VQ codebook sizes like 64, 128, 256. In this papaer the techniques of color traits transfer to greyscale images are revisited with various color spaces like newly introduced Kekre's Biorthogonal color spaces and RGB color space. The pixel window size used is of size 2x2. Color traits transfer to greyscale algorithms are tested over five different images for deciding the color space giving best quality of coloring. The experimental results show that the Kekre's Biorthogonal Green color space gives better coloring.

Keywords: Colorization, Kekre's Fast Codebook Generation(KFCG),Kekre's Biorthogonal Color Spaces,Vector Quantization(VQ).

1. INTRODUCTION

Colorization is the term which means to color any grey scale image. In digital image processing terms colorization of greyscale image is nothing but assigning the red, green and blue color component values to each grey value of greyscale image [2],[3]. Colorization is very difficult because it involves assigning three-dimensional (RGB) pixel values to an image which varies along only one dimension (luminance or intensity) [4]. Since different colors may have the same luminance value but vary in hue or saturation, the problem of colorizing greyscale images has no inherently 'unique' solution [4]. So user intervention becomes trivial in colorization process to select the 'better' match (red, green and blue values) for every greyscale pixel. In [2],[3] authors have proposed some of the simple approaches for colorization of greyscale images, where user intervention is needed only to select the source color image to be used to generate color palette. In [1], [5] different color spaces and pixel window sizes are worked out for coloring greyscale images. All these techniques gives the results subjective to the source color image considered for coloring are very heavy with respect to time complexity. To speed up the process different search algorithms are proposed in [2], [5]. But everywhere the size of source color image is assumed to be equal to or more than to be colored target greyscale image. The paper presents novel colorization technique where this size dependency of source color image and target greyscale image are taken out. Also newly introduced Kekre's Biorthogonal color spaces are used here and their performance is compared with and found better than RGB color space.

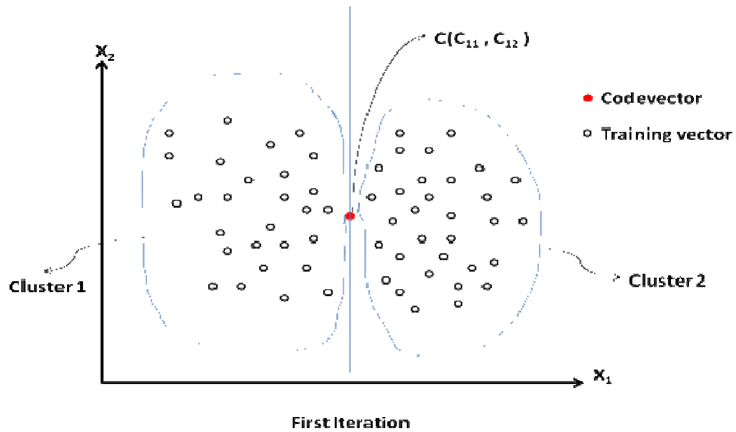
The proposed technique generates color palette using vector quantization codebook generation approach. Here Kekre's fast codebook generation (KFCG) [17], [21], [22] algorithm is used.

2. VECTOR QUANTIZATION(VQ)

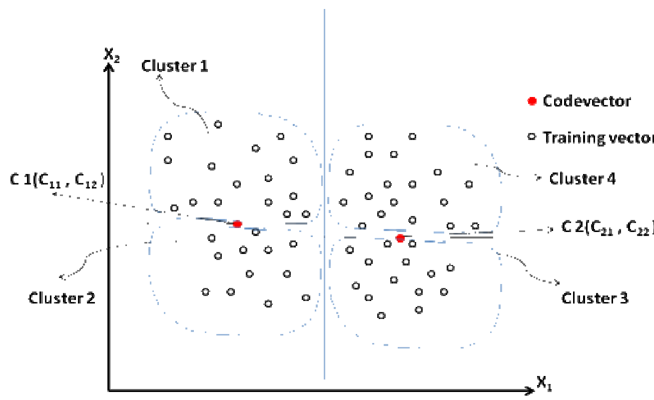
Vector Quantization (VQ) [15-21] is an efficient technique for data compression and has been successfully used in variety of research fields such as video-based event detection and anomaly intrusion detection systems, image segmentation [16-19], speech data compression [15], CBIR [21,22] and face recognition [20]. VQ [14-31] can be defined as the mapping function that maps k-dimensional vector space to the finite set **CB = { C1, C2, C3, ..., CN}**. The set CB is called codebook consisting of N number of codevectors and each codevector Ci = {ci1, ci2, ci3, ……, cik} is of dimension k. The key to VQ is the good codebook.

3. KEKRE'S FAST CODEBOOK GENERATION (KFCG)

Here the Kekre's Fast Codebook Generation algorithm given in [17],[21],[22] for image data compression is used. This algorithm reduces the time of code book generation. Initially we have one cluster with the entire training vectors and the code vector C_1 which is centroid. In the first iteration of the algorithm, the clusters are formed by comparing first element of training vector with first element of code vector C_1. The vector X_i is grouped into the cluster 1 if $x_{i1} < c_{11}$ otherwise vector X_i is grouped into cluster 2 as shown in Figure 1.a. where code vector dimension space is 2. In second iteration, the cluster 1 is split into two by comparing second element x_{i2} of vector X_i belonging to cluster 1 with that of the second element of the code vector. Cluster 2 is split into two by comparing the second element x_{i2} of vector X_i belonging to cluster 2 with that of the second element of the code vector as shown in Figure 1.b. This procedure is repeated till the codebook size is reached to the size specified by user. It is observed that this algorithm gives less error as compared to LBG and requires least time to generate codebook as compared to other algorithms, as it does not require any computation of Euclidean distance. The algorithm shown in Figure 1.a. and Figure 1.b. for two dimensional case it is easily extended to higher dimensions.



1.a



1.b

FIGURE1: KFCG algorithm for 2 dimensional case [22]

4. COLOR SPACES

A color model is an abstract mathematical model describing the way colors can be represented as tuples of numbers, typically as three or four values or color components. Color space is set of colors where the color model is associated with a precise description of how the components are to be interpreted.

A) RGB Color Space

RGB uses additive color mixing, because it describes what kind of light needs to be emitted to produce a given color. Light is added together to create form from out of the darkness. RGB stores individual values for red, green and blue.

B) Kekre's Biorthogonal Color Spaces

Novel Kekre's Biorthogonal color spaces are introduced here. Three versions of the same namely Kekre's Biorthogonal Red color space(YCrgCrb), Kekre's Biorthogonal Green color space(YCgrCgb) and Kekre's Biorthogonal Blue color space(YCbgCbr) have been used for colorization of greyscale images with Kekre's fast codebook generation (KFCG) algorithm.

a. Kekre's Biorthogonal Red color space(YCrgCrb)

To get YCrgCrb components we need the conversion of RGB to YCrgCrb components. The RGB to YCrgCrb conversion matrix given in equation 1 gives the Y, Crg, Crb components of color image for respective R, G, B components.

$$\begin{vmatrix} Y \\ Crg \\ Crb \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & -1 & 0 \\ 1 & 0 & -1 \end{vmatrix} \begin{vmatrix} R \\ G \\ B \end{vmatrix} \quad \ldots.(1)$$

The YCrgCrb to RGB conversion matrix given in equation 2 gives the R, G, B components of color image for respective Y, Crg, Crb components.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = 1/3 \begin{vmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{vmatrix} \begin{vmatrix} R \\ Crg \\ Crb \end{vmatrix} \quad \ldots.(2)$$

b. Kekre's Biorthogonal Green color space(YCgrCgb)

To get YCrgCrb components we need the conversion of RGB to YCgrCgb components. TheRGB to YCgrCgb conversion matrix given in equation (3) gives the Y,Cgr,Cgb components of color image for respective R, G, B components.

$$\begin{vmatrix} Y \\ Cgr \\ Cgb \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{vmatrix} \begin{vmatrix} R \\ G \\ B \end{vmatrix} \quad \ldots.(3)$$

The YCgrCgb to RGB conversion matrix given in equation (4) gives the R, G, B components of color image for respective Y,Cgr,Cgb components.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = 1/3 \begin{vmatrix} 1 & 2 & 1 \\ 1 & -1 & 1 \\ 1 & -1 & -2 \end{vmatrix} \begin{vmatrix} R \\ Cgr \\ Cgb \end{vmatrix} \quad \ldots.(4)$$

c. Kekre's Biorthogonal Blue color space(YCbgCbr)

To get YCbgCbr components we need the conversion of RGB to YCbgCbr components. The RGB to YCbgCbr conversion matrix given in equation (5) gives the Y,Cbg,Cbr components of color image for respective R, G, B components.

$$\begin{vmatrix} Y \\ Cbg \\ Cbr \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 0 & 1 & -1 \\ 1 & -1 & 0 \end{vmatrix} \begin{vmatrix} R \\ G \\ B \end{vmatrix} \quad \ldots.(5)$$

The YCbgCbr to RGB conversion matrix given in equation (6) gives the R, G, B components of color image for respective Y,Cbg,Cbr components.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = 1/3 \begin{vmatrix} 1 & 1 & 2 \\ 1 & 1 & -1 \\ 1 & -2 & 1 \end{vmatrix} \begin{vmatrix} Y \\ Cbg \\ Cbr \end{vmatrix} \quad \ldots.(6)$$

5. PROPOSED COLORIZATION TECHNIQUE

The colorization technique can be divided into main steps [1-5] as preparing color palette from source image and colorization of greyscale image using this color palette.

A. Color Palette Generation using KFCG

The steps generates color palette as the VQ codebook of source color image.

i. In case of Kekre's Biorthogonal Red color space convert source color image to Kekre's Biorthogonal Red color space using equation 1. Similarly in case of Green and Blue domain convert source color image to Green and Blue color spaces using equation 3 and 5 respectivly.
ii. This source color image is divided into pixel windows of size 2x2 (each pixel consisting of red, green and blue components).
iii. These are put in a row to get 12 values per vector (as 4 sets of Y, Crg and Crb values in YCrgCrb color space or 4 sets of R, G and B values in RGB color space or 4 sets of red, green and blue values in RGB color space). Collection of these vectors is a training set (initial cluster).
iv. The Kekre's Fast codebook generation algorithm is applied on this initial training set to obtain the codebook of specific size (here four sizes are considered 64, 128, 256).

B. Greyscale Image Colorization

The target greyscale image is divided into pixel windows of size 2x2. These 4 values are put into the row and are compared with GR component of all the codevectors in RGB color space, with Y component of the all the codevectors in YCrgCrb color space and with average of RGB for each of the four pixels of the codevector in RGB color space.

The closest match in the color palette is determined by calculating the Euclidean distance between Y or Average RGB of four values in color palette (Codebook) and greyscale pixel window values from the grey image. The direct Euclidian distance between pixel window row P and the color palette row Q of added columns can be given as below.

$$ED = \sqrt{\sum_{i=1}^{4} (Vpi - Vqi)^2} \qquad (7)$$

where, Vpi and Vqi be the considered pixels pixel window row P and color palette row of added columns Q respectively with size '4'. The respective red, green and blue component values for the grey pixels in considered pixel window of target image. Thus the target image could be colored using these red, green and blue planes generated by finding the best match for all non-overlapping grey target pixel windows from the color palette.

6. RESULTS AND DISCUSSION

Quality of greyscale image colorization technique is subjective to the source color image selected for coloring and also to the greyscale image to be colored. There are no objective criteria to check the performance of colorization method. At most one may take a source greyscale of source color image and try to recolor it using the colors from source color image. The mean squared error (MSE) difference between the original color and recolored images may serve as performance measure to see the quality of colorization method. So to compare the proposed colorization techniques here 5 color test images are recolored and the MSE differences are computed as shown in Table 1. From the table one could observe that improved colorization quality (reducing MSE) can be achieved by increasing the codebook size. Also Kekre's Biorthogonal Color space outperforms other color spaces in quality of colorization. Kekre's Biorthogonal color space with codebook size 128 gives lesser MSE among all colorspaces used here. In RGB and Kekre's Biorthogonal color spaces, the colorization methods using Kekre's Biorthogonal Red color space is better.

TABLE 1: MSE differences of original color image and recolored images

Color Space	MSE(for different code book sizes)			
	32	64	128	256
Mango				
RGB	2331.0	2213.2	2201.7	2199.2
YCrgCrb	1661.1	1642.1	1641.4	1616.3
YCgrCgb	686.1566	666.9238	628.8307	627.0860
YCbgCbr	855.8308	867.999	863.0653	867.2590
Shinchan				
RGB	3641.8	3567.5	3026.1	2972.1
YCrgCrb	2171.0	1982.6	2055.3	2180.9
YCgrCgb	2126.0	1900.8	2011.3	2164.4
YCbgCbr	2744.3	1703.1	1821.3	1881.8
Flower				
RGB	1566.2	1346.6	1104.0	1212.9
YCrgCrb	997.9115	763.0793	542.1344	582.8798
YCgrCgb	951.3074	715.4381	478.3759	525.0970
YCbgCbr	3017.8	3016.1	2925.9	2912.7
Toy				
RGB	3678.7	3766.1	3846	3754.1
YCrgCrb	297.9166	249.5779	258.6912	257.0715
YCgrCgb	295.1962	248.2651	264.9897	262.0023
YCbgCbr	328.4220	352.9238	372.9423	351.4189
Heart				
RGB	218.8196	214.7719	212.2312	207.7339
YCrgCrb	1101.3	1094.1	1092.7	1090.7
YCgrCgb	23.6774	16.5955	12.1940	10.7887
YCbgCbr	3892.0	3892.0	3892.0	3892.0

Figure 2 shows the sample images considered for checking quality of the proposed technique using various color spaces. Figure 3. shows original color of mango image and recolored mango images using proposed colorization techniques. The perceptibility of Kekre's Biorthogonal Green color space is better in all the results shown in Figure 2,Figure 3. In all Kekre's Biorthogonal Green color space is giving better coloring. In codebook sizes 128 is giving better recolored images which is also obvious, as the codebook size increases the color palette entries become more and hence more accurate options are available for colorization (better matches for grey pixel windows).Figure 4 and figure 5 shows the graph plotted between average values of MSE and the color spaces and different codebook sizes. From the graph it is clear that Kekre's Biorthogonal Green color space gives better result among all when the code book of size 128 is used.

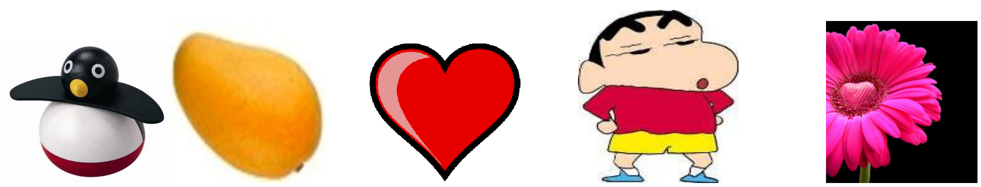


FIGURE2: Sample Images considered for checking quality of colorization techniques using various color spaces and KFCG.

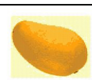
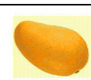
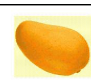
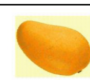
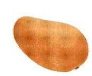
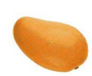
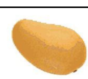
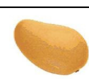
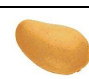
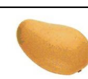
			
a. Original Image		b. Grey Image	
c to n Recolored Images using the original color image			
			
c. RGB-32	d. RGB-64	e. RGB-128	f. RGB-256
			
g. YCrgCrb -32	h. YCrgCrb -64	i.YCrgCrb-128	j. YCrgCrb-256
			
k. YCgrCgb -32	l. YCgrCgb -64	m. YCgrCgb-128	n. YCgrCgb -256
			
o. YCbgCbr-32	p. YCbgCbr-64	q. YCbgCbr-128	r. YCbgCbr-256

FIGURE 3: Original color Mango image and recolored Mango images using proposed colorization techniques

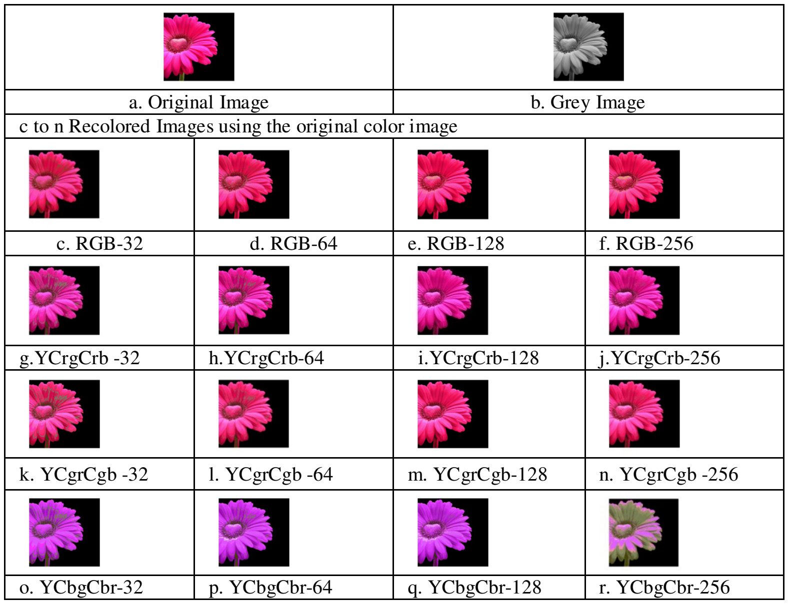


FIGURE 4: Original color Flower image and recolored Flower images using proposed colorization techniques

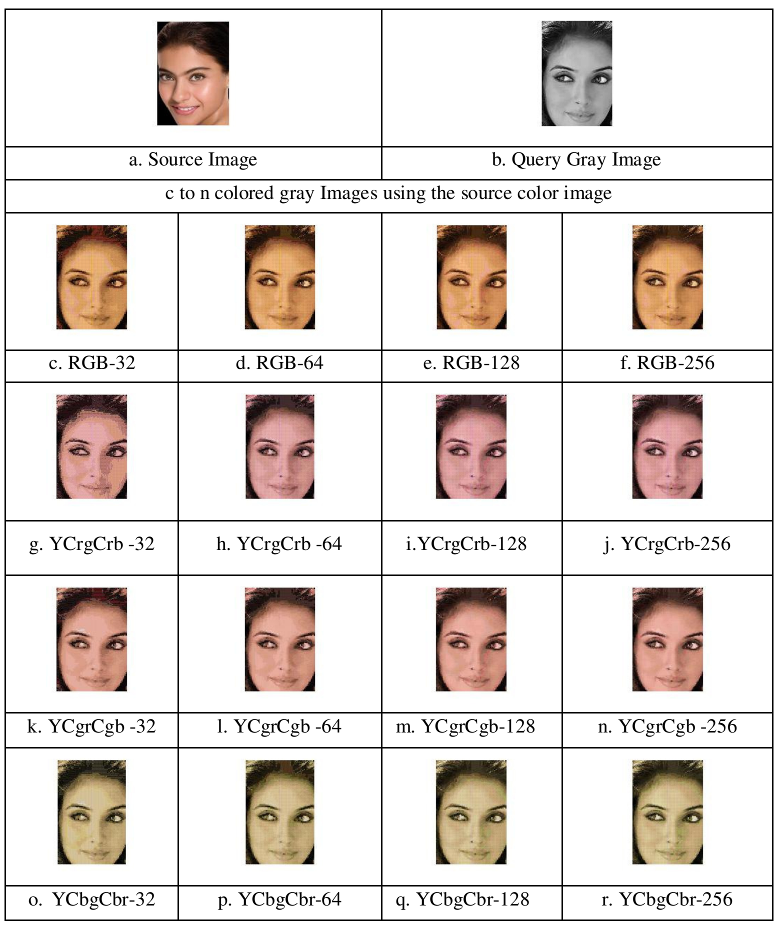


FIGURE 5: Source color image and colored Gray images using proposed colorization techniques

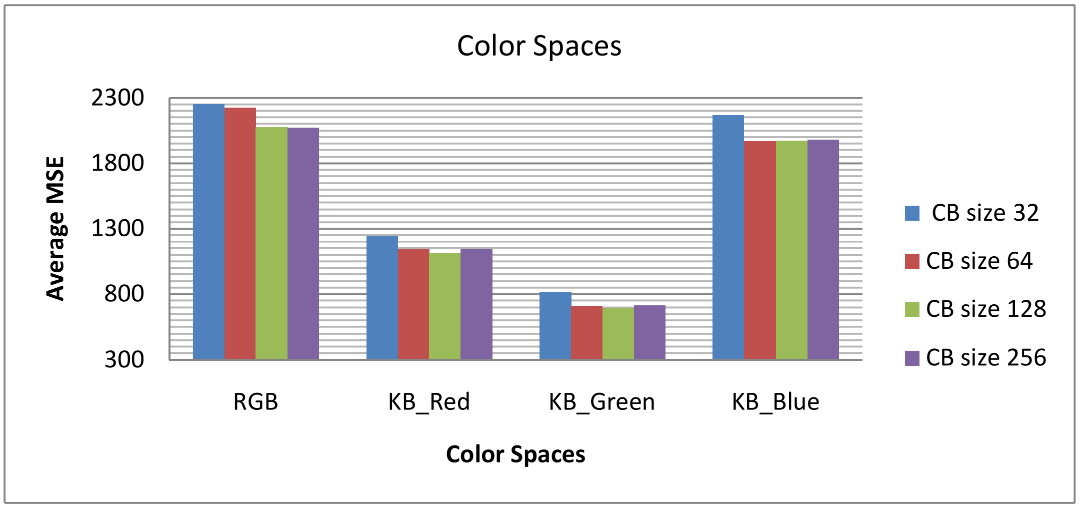


FIGURE 6: Average MSEs differences of images for different color spaces

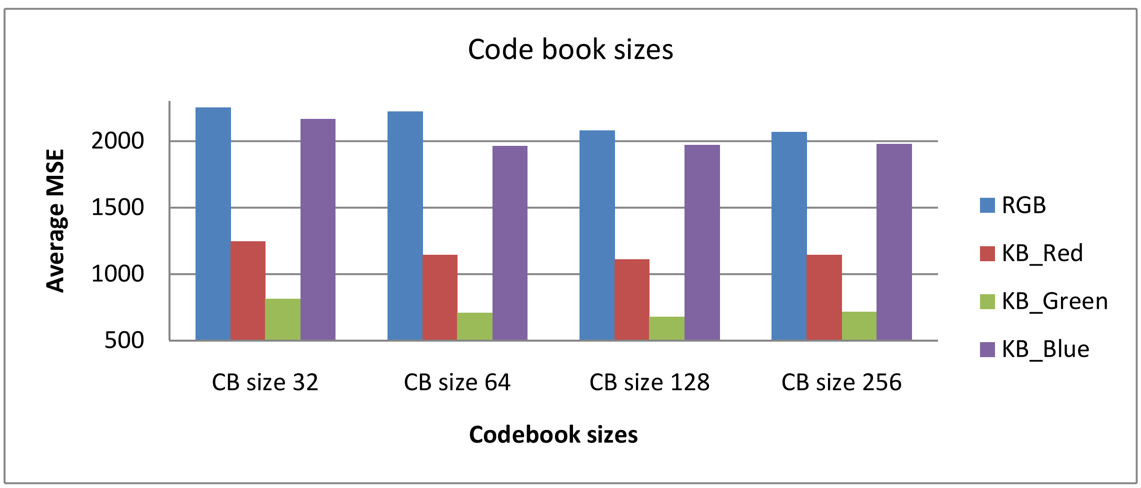


FIGURE 7: Average MSEs differences of images for different codebook sizes

7. CONCLUSION

Colorization improves the perceptibility of greyscale image to great extent. The technique of greyscale image colorization is presented in the paper with help of VQ codebbook generation algorithm KFCG and Kekre's Biorthogonal colr spaces. The technique helps to overcome the assumption of having source color image size bigger than the target greyscale for coloring considered in earlier approaches,as the fixed codebook size is used. In all 16 versions of proposed technique for 4 codebook sizes (32,64,128,256) with 4 color spaces like RGB and newly introduced Kekre's Biorhogonal Red, Green and Blue color spaces are proposed and compared in the paper. From the results one can conclude that, increasing codebook size improves (up to128)the quality of coloring up to certain extent. In all Kekre's Biorthogonal Green color space gives better colorization even at minimum codebook size.

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