ISSN (online): 2349-784X

A Review on Recent Pseudo-Coloring Techniques

R. Jayadevan
Assistant Professor
Department of Electronics and Communication Engineering
Sreepathy Institute of Management and Technology

Latha K. N
Associate Professor
Department of Electronics and Communication Engineering
Govt. Engineering College Thrissur

K. A. Navas
Principal and Professor
LBS College of Engineering Kasargode

Anjali Ananthan
M. Tech Student
Department of Applied Electronics and Communication
Thejus Engineering College

Abstract

Pseudo-coloring, a common task in image processing is used to color a grayscale image or to modify an existing color image with an intention of enhancing visual quality, imparting a visual appeal and highlighting specific features in the image. This paper presents a review of recent pseudo-coloring techniques in which the color is transferred from a source color image to a grayscale one. The techniques that we discuss here include the user interactive, semi-automated and automated pseudo-coloring approaches. The user interactive pseudo-coloring methods demand a complete user effort in selecting the source image as well as in color transfer process, whereas the task of user in semi-automated pseudo-coloring approaches is confined only to the selection of source image. In automated pseudo-coloring approaches, the user does not take any effort since the whole process is automatic. The performance of various pseudo-coloring techniques has been compared qualitatively based on the corresponding colored results and MOS values, and thereby identify the appropriate methods in each category.
Keywords: Color Transfer, Image Database, Image Retrieval, Luminance Matching, Pseudo-Coloring, Target Image

I. INTRODUCTION

Pseudo-coloring is a widely used technique for the colorization of grayscale images in order to enhance their visual appeal [5]. Color can be added to grayscale images such as old black and white photos, classic movies or scientific illustrations, which is a form of image enhancement. Pseudo-coloring finds its application in the areas of medical images, satellite images and even in military. The task of colorizing a grayscale image involves assigning three dimensional (RGB) pixel values to an image which varies along only one dimension (luminance or intensity). Since dissimilar colors may have the same luminance value but vary in hue or saturation, the problem of colorizing grayscale images has no inherently correct solution. Due to these ambiguities, human interface usually plays a large role in the colorization process. In pseudocoloring, where the mapping of luminance values to color values is automatic, the choice of the color map is commonly determined by human decision. So the amount of human interference needs for colorization may be decreased by transferring color from a source color image. The efficiency of pseudo-coloring technique is based on three main features viz; Distinguishability, Aesthetic sense and Extend of pixels colored. Distinguishability means to identify specifically the different features or objects in a pseudo-colored image. Aesthetic sense defines the sense of beauty and it differs from person to person. Extend of pixel coloring shows the total number of pixels that were colored by the pseudo-coloring technique.

In the conventional pseudocoloring techniques, the source or reference image is provided by the user along with query image. Interactive Local Color Transfer between Images [10] performs local color transferring rather than global one. This particular method is used when only the colors of certain part of an image needs to be changed. In this paper the task of partial image recoloring for the case, when user loosely specifies an object or region of interest at the target image is considered.

In this paper, Converting Grey-Scale Image to Color Image [6], the entire color mood of the source image is transferred to the target image by matching luminance and texture information between the images. Similar to other techniques, only chromatic information is transferred and it retains the original luminance values of the target image. In [8] the pseudo-coloring with the automatic source image retrieval based on texture similarity has been suggested. In this method pixel by pixel texture spectrum is calculated, which includes the texture unit, the texture unit number and the texture spectrum as well. A luminance and gradient matching procedure is used to select the best match of the query (target) image from the database in [15]. The color transfer process involves the application of luminance and texture matching. In [14] a pixel based pseudo coloring scheme is proposed where an interpolation scheme is used to deal with the problem of no luminance matching. A frequency domain approach to pseudo-coloring has been proposed in [16] in which the pseudo-coloring technique comprises of two steps, Source image selection from image database using CBIR based on wavelet transform [9] and pseudo-coloring query image using selected source image with the application of Histogram Interpolation algorithm. The field of pseudo-coloring grayscale images still facing major challenges which include the inefficiency in color transfer in case of luminance mismatch, failure to natural look after color transfer, extend of pixel coloring. In this context a review of the existing pseudo-coloring techniques has been carried out in this paper. This attempt is motivated by an intention to develop a novel automatic pseudocoloring approach that solves the above issues.

The paper is organized as follows. In section II a review of various pseudo-coloring techniques have been presented. The performance comparison of these techniques based on MOS value and colored results are given in section III. Section IV concludes the paper.

II. REVIEW OF PSEUDO-COLORING METHODS

In this section a brief review of the different pseudo-coloring approaches has been discussed separately. The techniques consider here include Interactive Local Color Transfer between Images (ICT), Converting Grey-Scale Image to Color Image (CTGI), Pseudo-coloring with Histogram Interpolation (PHI), Color Transfer To Grayscale Images Using Texture Spectrum (CTTS), Colorization of Grayscale Images Using Fully Automated Approach (CGFA), A Novel Frequency Domain Approach to Automated Pseudo-coloring of Images (FDPC). In all pseudo-coloring techniques both the source color image and target grayscale images are transferred to a decorrelated color space [1] prior to the start of color transfer. In the first three methods, user has to provide the source color image while the last three approaches do not require a user intervention. So the former is included under the category of user interactive or semi-automated pseudo-coloring techniques, while the later forms the automated pseudo-coloring techniques.

A. *User Interactive or Semi-Automated Pseudo coloring Techniques:*

In this subsection we discuss the concepts of pseudo-coloring techniques that include ICT, CTGI and PHI. In the forthcoming discussions we see a difference between the user interactive and semi-automated pseudo-coloring techniques.

1) ICT:

This methods offer a simple interactive algorithm based on local color statistics that allows altering color of only a part of an image, preserving image’s details and natural look. It falls under the category of user interactive pseudo-coloring techniques, where the color transfer between the source and target images requires complete user intervention.

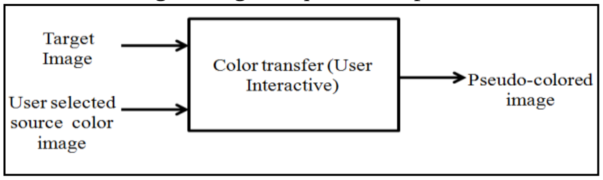

Fig. 1: User Interactive Pseudo-Coloring

Figure 1 shows the block diagram of user interactive pseudo-coloring approach. This approach is mainly used to alter the existing color of a region in an image. It demands the user intervention to loosely specify an object or region of interest at the target image to be colored. Selecting the object is supposed in terms of object’s color range. It is enough for the user to select a rectangular region, including main colors of the object of interest. The data of the selected region is used to calculate its color statistics using which the pixels belong or close to selected color range are estimated. It involves the calculation of Color Influence Map (CIM), which is a mask that specifies what parts of the target image will be affected according to the selected color range. The source color can be defined as a single color or a region of another image, that we will call the source image. In this case source color statistics are also calculated. Finally the target image is re-colored according to the prepared CIM and the stored color statistics.

2) CTGI:

This is a semi-automated approach of pseudo-coloring in which the color transfer process is automatic but selection of a source color image requires user interface.

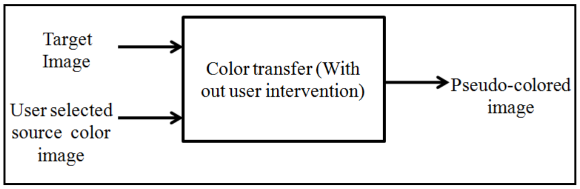

Fig. 2: Semi-automated Pseudocoloring

The general procedure for color transfer requires a few simple steps. First each image is converted into lαβ color space [3]. Next, we go through each pixel in the grayscale image in scan-line order and select the best matching sample in the color image using neighbourhood statistics. The best match is determined by using a weighted average of pixel luminance and the neighbourhood statistics. The chromaticity values (channels) of matching pixels are then transferred to the grayscale image to form the final image.

3) PHI:

In this approach, a pixel based pseudo coloring is presented. PHI is a semi-automated approach which consists of two parts: luminance matching and pixel coloring. Given a grayscale input image and a color source image, luminance matching between the two images are performed. If there is no matching between, an interpolation scheme [11] is used to interpolate the chromatic histograms of source image. By this doing, it ensures each pixel in the input image has its corresponding chromatic information in the source image. By the luminance and chromatic information, a colored input image is obtained.

B. Automated Pseudo-Coloring Techniques:

CTTS, CGFA and FDPC techniques fall under the category of automated pseudo-coloring techniques. In these methods the source image is retrieved automatically from a database of images by some matching procedure, so that user takes no effort in source image selection as well as in color transfer process. The basic concept of the automated pseudo-coloring technique is well depicted in figure 3. Here the coloring process is initiated by some matching procedure between target image and database images in order to retrieve the closest match. To simplify the matching procedure, a feature database could be formed so that matching will be carried out between the features of database images and that of target image.

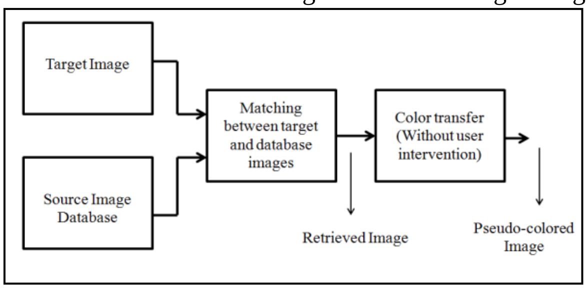

Fig. 3: Automated Pseudo-Coloring Technique

1) CTTS:

Color Transfer to Grayscale Images Using Texture Spectrum (CTTS) is a fully automated approach towards pseudo-coloring. In this method the source image is automatically retrieved based on texture spectrum similarity [1]. The target grayscale image is treated as query image and retrieves the image whose texture feature is similar to the texture of the query image. We calculate the texture spectrum pixel by pixel, which includes the texture unit, the texture unit number and the texture spectrum. Then, the texture spectrum is used to compute the similarity between two images. If the two images are similar enough, the retrieved image can be used as the source color image for color transfer. The determination of texture spectrum involves the computation of relative intensity relations between the pixels in a small neighbourhood and not on their absolute intensity values. The color transfer algorithm consists of luminance remapping of source image to linearly shift. Then, we sample source color pixels with texture spectrum. Next, go through each pixel in the target image and find the matched pixel from the source image sampling respectively.

2) CGFA:

This method performs the coloring procedure without human interference. In this technique, a luminance and gradient matching procedure is used to select the best match of the query (target) image from the database. For each image in the database, a signature is created, that consists of values of its luminance histogram and gradient histogram. Then store the signatures into a database to make the matching procedure easy. An image similar to the query image may be retrieved from the database by matching their signatures. To determine the best match, a correlation between the query and database signature vectors is carried out and selects that image with largest correlation as the source image. The color transfer process is initiated by the conversion of both images into a de-correlated color space. Then apply luminance and texture matching i.e., for each pixel in the grayscale (target) image in scan-line order, the best matching sample in the color (source) image is selected, based on weight of the luminance (50%) and the texture (50%) matching. Once the best matching pixel is found, its chrominance values are transferred to the target pixel while the original luminance value of the target pixel is retained.

3) FDPC:

This technique has been a novel automated pseudo-coloring approach in which the novelty is reflected in the choice of source image selection algorithm which works on the principle of Content Based Image Retrieval (CBIR) [4], [7] using wavelet transform. The two basic steps involved in this automated pseudo-coloring technique are: Source image selection from image database using CBIR based on wavelet transform and Pseudo-coloring query image using selected source image with the application of Histogram Interpolation algorithm. The source image selection procedure involves three phases. First phase is the decomposition of images in database using tree structured wavelet transform [2] resulting in the formation of sub-bands. The level of decomposition depends on the size of image and energy content in each sub-band. In the second phase, feature vector calculation of each image in the database is done. The feature parameters selected in this work are standard deviation and energy. These feature parameters corresponding to each of the sub-bands at each decomposition level are used to construct a feature vector. The final phase involves the selection of the most suitable source image from database. In this step, feature vector for query image is computed by the same procedure and then Manhattan distance [12] is used to compute similarity between query image and list of source images in database. Manhattan distance D_{qi}^{M} is given by

$$D_{qi}^{M} = \sum_{j=1}^{n} |f_{qj} - f_{ij}|$$

Where f_{qj} and f_{ij} are the feature vectors of query and database images respectively and n is the length of feature vector. The image in database having the smallest Manhattan distance is identified as the source image. The source thus selected is used for pseudo-coloring the query image. The color transfer is implemented using Histogram interpolation method which proves to be better compared to other color transfer procedures, since this method works well even in the absence of luminance matching.

III. RESULTS AND DISCUSSION

This section provides a performance comparison of different pseudo-coloring techniques we have discussed. The comparison is based on the visual quality of images produced by different methods. The popular subjective quality measure, Mean Opinion Score (MOS) was used as visual quality measure because subjective evaluation is superior to quantitative measures such as Peak Signal to Noise Ratio (PSNR), Weighted PSNR (WPSNR), VSNR (Visual SNR), Visual Information Fidelity (VIF) etc [13]. We first discuss the performance of user interactive process ICT, since this method seems to be a different approach because of full user interaction in the whole process. Then we discuss the efficiency and quality of the color transfer process employed in different pseudo-coloring techniques such as CTGI, PHI, CTTS and CGFA. This comparison is carried out with help of a graph depicting the MOS value for different aspects like Distinguishability, Aesthetic sense, Extend of pixel coloring, Sharpness and Natural feel. Since the color transfer algorithm used in FDPC is same as PHI, we do not consider FDPC in this analysis. But a comparison of automated techniques based on the retrieved source image and obtained colored results has also been included here, which consider the performance of FDPC. Figure 4 shows the ICT pseudo-coloring. Figure 4(a) is the user selected reference image for color transfer, 4(b), the target image. The user loosely specifies a portion (flower) inside the target image whose color is to be modified. Similarly the user selected a region (butterfly) inside the source image from where the color is transferred. Figure 4(c) gives the resulting image after color transfer.

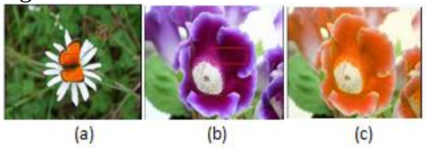

Fig. 4: (a) Source Image, (b) Target Image, (c) Colored Image

It is very obvious that the colored image has good sense of beauty (aesthetic sense), natural feel as well as the sharpness is well maintained. This is a time consuming task if the intention of coloring is not just confined to entertainment. From figure 4(c), the color transfer algorithm in ICT modifies all the pixels in target image whose color value is close to the selected color range, i.e. the color of remaining flowers other than the selected one are also modified. Figure 5 shows the graph depicting performance comparison of color transfer algorithms in different pseudo-coloring techniques. This comparison is based on features like Distinguishability, Aesthetics sense, Pixel coloring, Sharpness and Natural feel. It is very obvious from the graph that algorithm employed in PHI technique is superior to other algorithms in terms of Distinguishability, Aesthetic sense, Pixel coloring and sharpness while Natural feeling is well maintained in CGFA compared to other methods. Now we consider the performance of automated techniques such as CTTS, CGFA and FDPC. Figure 6 (a) shows the target grayscale image to be colored. Figure 6 (b) represents the retrieved source image using CTTS algorithm, where as figure 6 (c) indicates the retrieved source image using CGFA and FDPC techniques. This clearly shows that the retrieval algorithm used in CTTS is not much efficient to yield the appropriate match, where as the CGFA and FDPC retrieval algorithms yields well matched source image from the database. The image in figure 6(d) represents the colored result using CTTS, while figures 6(e) and 6(f) are the colored results obtained using CGFA and FDPC techniques respectively. Pseudocoloring methods in which the reference image is selected with the user intervention is much time consuming, since the user himself needs to check each reference image in the database. In general the FDPC techniques take nearly one to two minutes to obtain the colored result, which is very less compared to user interactive techniques. In user interactive process the situation gets worse as the size of database is increased which will not affect the automated techniques.

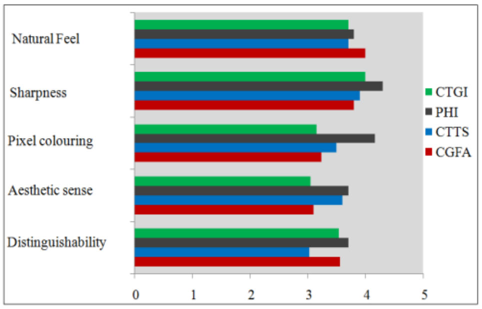

Fig. 5: Comparison of Different Pseudo-Coloring Techniques Based On Various Aspects.

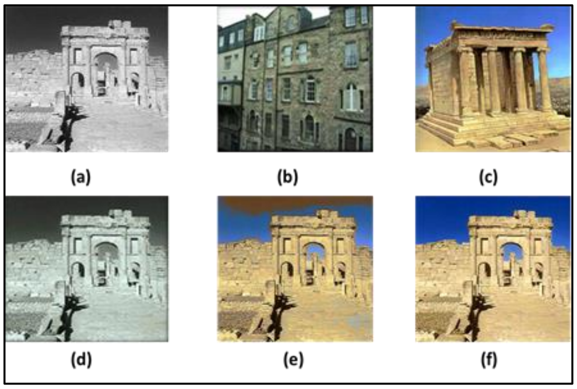

Fig. 6: Comparison of CTTS, CGFA and FDPC pseudo-coloring techniques based on the results. (a) Target grayscale image, (b) Retrieved source image using CTTS algorithm, (c) Retrieved source image using CGFA and FDPC techniques, (d) Pseudo-colored image using CTTS, (e) Pseudo-colored image using CGFA, (f) Pseudo-colored image using FDPC.

IV. CONCLUSION

In this paper a comparison study of different pseudo-coloring techniques have been discussed. The discussion aids in categorizing the techniques as user interactive, semi-automated and automated pseudo-coloring approaches. The comparison results showed that Histogram Interpolation technique scores better compared to other semi-automated pseudo-coloring approaches where as the FDPC methods is superior among automated approaches. The author is doing his research to enhance the pseudo-coloring approach by implementing the source image retrieval system using contourlet transform. The refinement of the color transfer process is also a major part of his research so that the newly developed algorithm produces results which are devoid of all types of visual artifacts.

REFERENCES

[1] D.C. He & L. Wang, ‘Texture Features Based on Texture Spectrum”, Pattern Recognition, Vol.24, No. 5, pp. 391-399, 1991.
[2] T. Chang and C.C. Kuo, “Texture Analysis and Classification with Tree-Structured Wavelet Transform,” IEEE Trans. Image Processing, Vol.2 No.4, pp.429-441, 1993.
[3] Ruderman, D.L., Cronin, T.W. and Chiao, C.-C., Statistics of cone responses to natural images: implications for visual coding, Journal of the Optical Society of America A, 15(8), pp. 2036-2045, 1998.
[4] Arnold. W. M. Smeulders, M. Worring, S. Satini, A. Gupta, R. Jain, “ Content –Based Image Retrieval at the end of the Early Years,” IEEE Transactions on Pattern analysis and Machine Intelligence, vol. 22, no. 12,pp. 1349-1380 , Dec. 2000.
[5] Erik Reinhard, Michael Ashikhmin, Bruce Gooch, Peter Shirley, Color Transfer between Images, IEEE Trans. Computer Graphics and Applications,Vol. 21, no. 5, pp. 34-41, 2001.
[6] Govind Haldankar, Atul Tikare and Jayprabha Patil, Converting Gray-Scale Image to Color Image, Proceedings of SPIT-IEEE Colloquium and International Conference, Mumbai, India. Vol.1 pp. pp. 189-192.
[7] Manesh Kokare, B .N.Chatterji and P.K.Biswas, “A Survey on current content based Image Retrieval Methods,” IETE Journal of Research, vol. 48, no. 3 &4, pp. 261-271, 2002.
[8] Ye Ji, Hong-Bo Liu , Xiu-Kun Wang, Yi-Yuan Tang, Color Transfer to Gray scale Images using Texture Spectrum, IEEE Third Int. Conf. on Machine Learning and Cybernetics, Shanghai, Vol.no. 7, pp. 4057 - 4061, 26-29 August 2004.
[9] Manesh Kokare, B.N. Chatterji and P.K. Biswas, Wavelet Transform Based Texture Features For Content Based Image Retrieval, PhD Thesis, Electronics and Electrical Communication Engineering Department, Indian Institute of Technology, Kharagpur.
[10] Alla Maslennikova, Vladimir Vezhnevets, Interactive Local Color Transfer Between Images, International Conference, GraphiCon'2007 Russia, Moscow, June 23-27, 2007.
[11] Cheng-Hsiung Hsieh, Ren-Hsien Huang and Ting-Yu Feng, “One-Dimensional Grey Polynomial Interpolators for Image Enlargement,” IEEE/ACIS Int. Conf. on Computer and Information Science, pp. 450-455, Melbourne, Australia, 2007.
[12] Dar-Jen Chang, Ahmed H. Desoky, Ming Ouyang, Eric C. Rouchka, Compute pair-wise Manhattan distance and Pearson correlation coefficient of data points with GPU, Computer Engineering & Computer Science Department University of Louisville, Kentucky, USA.
[13] K. A. Navas, Aravind M. L, Sasikumar M, A Novel Quality Measure for Information Hiding in Images, Proc. IEEE Computer Society Conference on Computer Vision and Pattern recognition workshops, 23-28 June 2008, Alaska, US.
[14] Cheng-Hsiung Hsieh, Chih Ming Lin and Fung Jung Chang, Pseudocoloring with Histogram Interpolation, Ninth International Conference on Hybrid Intelligent Systems, 2009.
[15] Yogesh Rathore, Avinash Dhole, Ramnivas Giri, Umesh Agrawal, Colorization of Gray Scale Images using Fully Automated Approach, International Journal of Electronics & Communication Technology, Vol.1, no.1, pp. 16-19, December 2010.