New Restoration Method for damage data base of films and pictures

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ABSTRACT

In thic paper, we introduce a new algorithm which restores colour for old films and photos. The algorithm is based on Affine colour fading model initiated by R. Gschwind va F. Frey trong and also based on new prosposed multi colour scheme in colour space RGB.

1. Introduction

Restoring lost data is an important problem in many areas, such as science, technology, economics, and other areas of human social life. The restoration of lost data is complicated, requiring the use of different scientific methods. In the framework of this article, the authors are only limited mention a method for recovering color photos and maps were aging.

Color photos and color film reflect the actual world more exact than black and white images, black and white movies. However, due to the characteristics of materials and manufacturing technology, color materials less durable than black and white materials, the most common is the discoloration and deterioration contrast. After a storage time of about 10 years, the images are often blurred and color imbalance, causing image quality feels very much impaired. The imaging element in black and white film is pure silver particles, very sustainable for the chemical reaction. The imaging element in the color film is the organic dye particles, biodegradability in hot and humid conditions or long lighting. So black and white movies and black and white images are less affected by temperature and humidity of the environment than the color film, color images. Furthermore, the decay rate of the different colors is also uneven leading to an imbalance of color, rapidly reduce image quality.

Since the mid-1990s thanks to the rapid development of digital and digitized image devices, people began to study methods of recovering faded color image with digital image processing technique. However, the results are still limited. The modern restoration system for trading still requires human intervention at many stages and have a very high cost (eg the Da Vinchi Systems were offered for around 2 million pound).Therefore the study for new effective method is still ongoing.

The paper is organized as follows. The section 2 presents fundamental mathematical models of discoloration and the basic methods of restoring color. The section 3 describes the mathematical model of new color restoration method. The section 4 some application results. Finally, some conclusions have been made.

2. Models and Methods of Restoring Color

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In general, the restoration method of faded color image includes the following steps:

- Establish a mathematical model describing the process of film faded with time, temperature, humidity, and the intensity of light impact on image materials;

- Construction of algorithms, allowing redefined original color density, based on the measurements of color density and the parameters of the bleaching model.

Mathematical Model of Discoloration

To be able to use the digital processing technique for the retrieval of the missing color components from old faded images, one needs to build mathematical model that describes the color density of the film layers, which contains all the main factors affecting the discoloration, such as storage time, temperature, humidity storage environment, and the intensity of light impact on the image materials. Since the late 1990s, based on experiments on different types of color film, in various storage conditions, R. Gschwind, F.S. Frey and L. Rosenthaler (1995) have built a model, which quite accurately describes the process of fading color film and color photographic paper types. This model has been tested and widely accepted.

Denote*(r',g',b')*- luminance of pixels*(i,j)* of the image faded and*(r,g,b)*- the initial luminance (we need to determine) of that pixels. A valuable model for fading can be described by the following linear bleach equation:

$$\begin{pmatrix} r' \\ g' \\ b' \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} r \\ g \\ b \end{pmatrix} + \begin{pmatrix} a_{41} \\ a_{42} \\ a_{43} \end{pmatrix}, \qquad (2.1)$$

With $\{a_{ij}\}$ - the elements of the bleach matrix A.

The Methods of Restoring Color

Generally, the methods of restoring color have been proposed are based on model (2.1) , or based on the Retinex theory (Land, 1977) on the mechanism of visual perception of color.

Method based on Linear Bleaching Model

R. Gschwind,FS. Frey and L.Rosenthaler (1995) have identified the parameters $\{a_{ij}\}$ in (2.1) for a variety of popular films in different conditions and duration of storage. However the actual conditions of Vietnam is often not known exactly what types of film as well as time and conditions to preserve them. Therefore, the above parameters are only for reference.

From (2.1), to determine the 12 parameters $\{a_{ij}\}$, it is necessary to know the initial luminance*(r,g,b)* at least four pixels. As usual there is no information about the original image, so the identification of four pixels is very difficult. In Restoration of Faded Color Digital Motion Pictures (2000), M. Chambah and B.Besserer have proposed method to estimate the value of four pixels original, based on the familiar color usually appears in the image, such as skin color characters, foliage color, color blue, etc….

The Balancing Methods

The color balancing methods are proposed in order to correct the color deviation, when photos are taken in non-standard lighting conditions. These methods are based on the properties of color perception of the visual. Usually, people do not identify the colors in dark areas of photos. These areas are recognized as the gray area. Moreover, in the photo quality standards, the average luminance of the color channels usually equal. Analogous, the brightest area in the image is perceived as white. Therefore, the method of color balance, usually divided into two types: the method of gray areas (Grey World Method) and white areas methods (Max White Method).

• *Grey World*: This method assumes the average luminance of the color channels *R,G,B*in the image are equal. Denoting the average luminance of the color channels *R, G, B* respectively *mR*, *mG*, *mB*. And suppose that the average brightness of *G* channel is constant. Then the coefficients of *R* and *B* channels by channel *G* will be determined as follows:

$$a_R = mG / mR \quad , \quad a_B = mG / mB$$

• *Max White*: Max White method assumes that the brightest point in the three *R,G,B* channels are reaching the maximum value and by $(2^n, 2^n, 2^n)$, where n is the number of bits representing a transmission channel (normally $n = 8$, $n = 16$). Magnification of the channels will be determined as follows:

$$a_R = 2^n / R_{Max} \quad , \quad a_G = 2^n / G_{Max} \quad , \quad a_B = 2^n / B_{Max} \; .$$

Based on two main ideas presented above, recently, many color balancing methods have been proposed (Lam, 2000 and Ahmed, 2009).

3. New Model of Restoring Color

An Algorithm for Color Restoration of Old Images and Film (Pham and Nguyen, 2009) proposed a new color restoration approach for model (2.1). The main idea of this approach can be described as follows.

Let $X' = (r', g', b')^T \in R^3$ - Pixels measured; $X = (r, g, b)^T \in R^3$ - The original pixels (not discolored);

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$$ - Bleaching matrix size (3x3);

$b = (b_1, b_2, b_3)^T$ - Vector indicating the aging film substrate.

The bleaching model takes the following form:

$$x' = Ax + b \qquad (3.1)$$

Then determine 12 parameters a_{ij}, b_j, and the original value x can be calculated by the following formula (3.2):

$$x = A^{-1}(x - b) \tag{3.2}$$

New construction method is performed in two steps:

Step 1. Consider a special form of (3.1) as follows:

$$x^{'} = \begin{pmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{pmatrix} x^{(1)} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} \tag{3.3}$$

Since the coefficients outside the main diagonal of the matrix A is usually very small compared to the elements on the main diagonal, so (3.3) can be considered as model approximation of (2.1). Determine the value of two pixels of the image to find $x^{(1)}$, and then define the parameters of (3.3). Similarly in the Max – White technique, choose the most bright point (for a value (255, 255, 255)) and the darkest point (for a value (0, 0, 0)) of image *x'*.

Step 1 allows recovering quite accurate color in bright and darkest parts of the image. At the same time the main diagonal elements of *A* helps restore the amplitude of the contrast on the color channel *R*, *G*, *B* separately. However, in areas where the average luminance and especially, in the area near the gray, there will be the color cast.

Step 2: The step 2 is to build up the chart of integrated average luminance in (*R*, *G*, *B*) space which allows eliminating the color cast.

Unlike normal brightness chart (histogram) is built on each separate color channels, chart of integrated average luminance built in space (*R*, *G*, *B*) as shown in Figure 1.

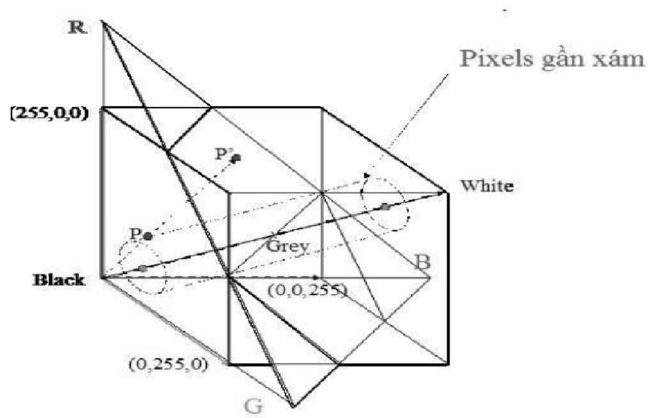

Figure1. Color space (R, G, B)

Define "pixels almost gray". Without the loss of generality, assume that the first image is digitized 24 bit (8 bits per color channel). For each pixel $x=(r,g,b)\in I$, the point x is almost gray pixels if:

$$(\max\{r;g;b\} - \min\{r;g;b\}) \leq S_{\min} .$$

Proposed algorithm mainly focus on adjusting the points with the average luminance and especially the almost gray points.

At plane [*R*, *G*, *B*] (Figure 1). The Descarte coordinates of the vertices *R*, *G*, *B* are *R* = (384, 0, 0); *G* = (0, 384, 0); *B* = (0, 0, 384). Call O_p is the barycenter of the triangle *RGB*, then descarte coordinates of O_p is:

$$\vec{O}_p = (128,128,128) \tag{3.4}$$

Barycenter coordinates of O_p in the plane [*R*, *G*, *B*] are:

$$O_p = \frac{1}{3}R + \frac{1}{3}G + \frac{1}{3}B \tag{3.5}$$

Denote $\lambda = \|\vec{O}_p\|$, Then the projection of the point x = (r, g, b) on the plane [*R*, *G*, *B*] be represented by the formula: $\vec{x}' = \vec{x}\dfrac{\lambda}{\langle \vec{x}, \vec{O}_{p0} \rangle}$, with $\vec{O}_{p0} = \dfrac{\vec{O}_p}{\lambda}$ (3.6)

Let $x=(r,g,b)\in[R,G,B]$ be the representative of x in orthogonal coordinate systems. Let $M=r+g+b,$ then representation of x in barycenter coordinates on [*R, G, B*] will be defined by the following

$$x = \rho R + \gamma G + \beta B \text{, With } \rho = \frac{r}{M}, \gamma = \frac{g}{M}, \beta = \frac{b}{M}$$

Let construct the chart of the triangle *RGB* (Figure 2). Consider the barycenter coordinate system in the plane [*R, G, B*]. For a given integer *N* we divide the interval [*0, 1*] into 2^N equal segment by the dividing point:

$$n_0 = 0, n_1 = \frac{1}{2^N}, ..., n_i = \frac{i}{2^N}, ..., n_2N = 1$$

Then in the barycenter coordinate system (Figure 3), the point x will belong to the plane [*R, G, B*] if and only if $x=(\rho,\gamma,\beta);\ \rho+\gamma+\beta=1.$

So the segments:

$$R_0 = \left[0, \frac{1}{2^N}\right); R_1 = \left[\frac{1}{2^N}, \frac{2}{2^N}\right); ...; R_{2^N-1} = \left[\frac{2^N-1}{2^N}, 1\right];$$ similar segments for the *G* and *B*.

The point $(\rho,\gamma,\beta)=(n_i,n_j,1-(n_i+n_j))$, with *i,j =0,1,. ..,2N, n_i +n_j ≤ 1*. Determine a partition of the equilateral triangles in *R, G. B*

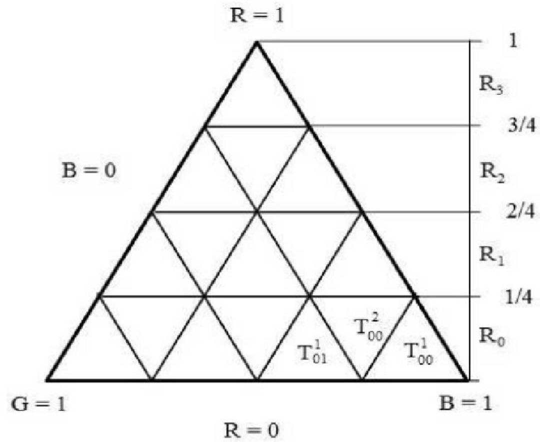

Figure 2 . Partition RGB triangle with *N = 2*

Denote $\beta_{\mathrm{ij}} \triangleq 1-(n_i+n_j)$ such that $(n_i+n_j\le 1)$. Let $i,j=0,1,...,2^N-1$ such that $(n_i+n_j\le 1)$, then the rhombus defined by four points $(n_i,n_j,\beta_{i,j,})$, $(n_{i+1},n_j,\beta_{i+1,j,})$, $(n_i,n_{j+1},\beta_{i,j+1,})$, $(n_{i+1},n_{j+1},\beta_{i+1,j+1,})$, or in other words, the rhombus is determined by four edges $\rho=n_i$; $\gamma=n_j$; $\rho=n_{i+1}$; $\gamma=n_{j+1}$whichcontains two equilateral triangles dividing by $\beta=\beta_{i,j+1}=\beta_{i+1,j},$. Denote $T^1_{i,j}$ the class Type I of the triangle which has the coordinates satisfying $\rho+\gamma+\beta<1$.The triangles with $\rho+\gamma+\beta\ge 1$called Type II and denoted by $T^2_{i,j}$. Also have some other rhombus determined as above but with only triangles of Type I in the triangles *RGB* along line *B = 0*. Therefore, the triangle *RGB* are partitioned into triangles $T^1_{i,j}$ and $T^2_{i,j}$

To make the pixels have average brightness falls into each equilateral triangles of above partition, let build a matrix of counter point *A[i,j], i,j = 1, 2, ..., 2^N+1*. This matrix consists of (2^N + 1) × (2^N + 1) elements. Number of pixels fall into the triangle $T^1_{i,j}$ inscribed in the element *A [i+1, j+1]* and number of pixels fall into the triangle $T^2_{i,j}$ inscribed in the element *A* [(2^N+*1*) - *j,* (2^N+*1*)- *i*], which symmetry across the diagonal line.

The next step is to determine the histogram. First calculate the barycenter of the equilateral triangle of partition triangle *RGB*.

Let $\Delta=\dfrac{1}{3.2^N}$ (ie 1/3 of each small piece of $1/2^N$).

For triangle Type I with the coordinates of the edge $\rho=n_i,\gamma=n_j,\beta=n_k$, let have $n_i+n_j+n_k<1$, and the bary center coordinates determined by:

$$\rho^1_c=\frac{i}{2^N}+\Delta;\ \gamma^1_c=\frac{j}{2^N}+\Delta;\ \beta^1_c=\frac{k}{2^N}+\Delta\ , \qquad (3.7)$$

With the triangle Type II, $T^2_{i,j}, n_i + n_j + n_k \geq 1$ barycenter coordinates will be:

$$\rho^2_c = \frac{i}{2^N} + 2\Delta; \gamma^2_c = \frac{j}{2^N} + 2\Delta; \beta^2_c = \frac{k}{2^N} + 2\Delta \qquad (3.8)$$

Then the barycenter of the histogram is determined by the formula:

$$P = \frac{1}{M} \sum_{i,j} (x^1_{ij} c^1_{ij} + x^2_{ij} c^2_{ij}) \qquad (3.9)$$

here:

x^1_{ij} - The number of pixels fall into triangles T^2_{ij}; x^2_{ij} - The number of pixels fall into triangles T^2_{ij};

$C^1_{ij} = (\rho^1_c, \gamma^1_c, \beta^1_c)$ - The barycenter of the triangle Type I, T^1_{ij}; $C^1_{ij} = (\rho^1_c, \gamma^1_c, \beta^1_c)$ - The barycenter of the triangle Type II, T^2_{ij} $M = \sum_{ij} (x^1_{ij} + x^2_{ij})$ - Cumulative number of pixels in the histogram.

From the barycenter coordinates of the histogram and the barycenter of *RGB* triangle, have color cast vector (see Figure 4):

$$\vec{F} = P - (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) \qquad (3.10)$$

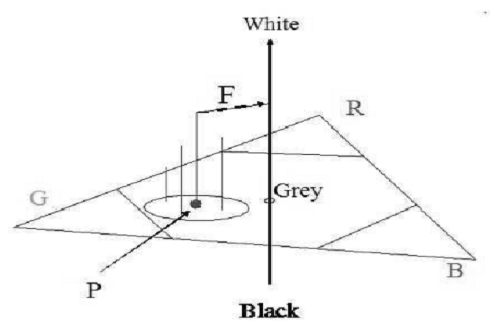

Figure 3. Color cast vector

With color cast vector $\vec{F} = (F_R, F_G, F_B)$, we use the technique of "gamma correction" to adjust the color values of the pixels of $x^{(1)}$, with gamma values are defined as follows for each color:

$$\gamma R = \frac{\ln(0,5 - F_R)}{\ln(0,5)}; \gamma G = \frac{\ln(0,5 - F_G)}{\ln(0,5)}; \gamma B = \frac{\ln(0,5 - F_B)}{\ln(0,5)}.$$

The above formulas (3.4)-(3.10) help us to find the approximation $x^{(2}$. The results are a new approximation $x^{(2)}$which is better than the original image. The image $x^{(2)}$is used to determine the entire 12 parameters of the model (2.1). Then to use the formula (3.2) to restore color to the whole of the video images needed restoration.

4. Application Results

The above mentioned algorithm is applied to restore photos and map that are too old and blurry.

The Data – Tool software is programmed in the C language, integrated with the support of a few Tools in Matlap. The software is effective and stable, compatible with personal computers with normal configuration on Windows XP2 or higher.

- Input Data: old image files that are blurry, faded, torn at corners... in such formats as *.jpg;*.bmp;*.png;*.tif.
- Output Data: The processed products are saved in *.pdf and could be viewed on computers or printed.

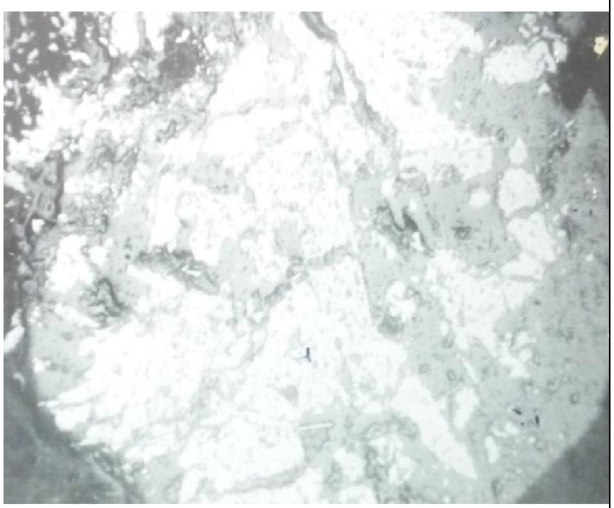

Figure 4. Original picture

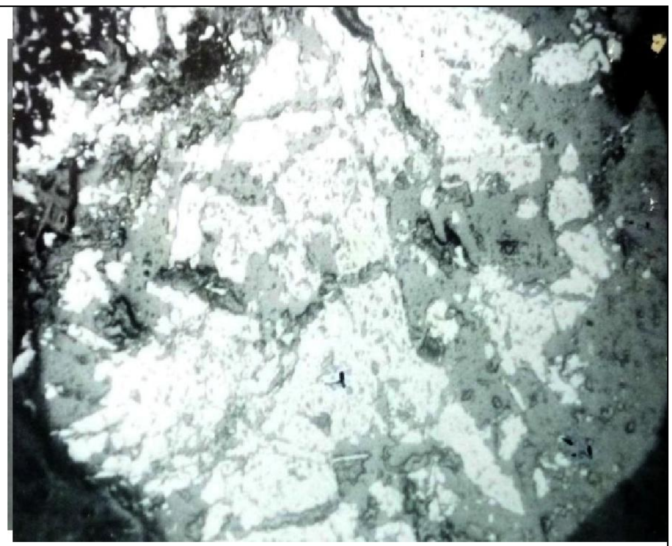

Figure 5. After restoration

References

[1]. Gschwind R., Frey F.S.,& Rosenthaler L.(1995). Electronic Imaging: A Tool for the Reconstruction of Faded Color and Color Photographs Movies, *Proc. SPIE Image and Video Processing III,* 57-63.

[2]. Chambah M. and Besserer B(2000). Restoration of Faded Color Digital Motion Pictures, *CGIP Conf. Proc*, 338-342.

[3] Land E, 1977. The Retinex Theory of Color Vision, *Scientific American, Vol 237, N6*, 108-128.

[4] Lam E, 2005. Combining Gray World and Retinex Theory for Automatic White Balance in Digital Photography, *ISCE*, 134-139.

[5] Ahmed A. M. T, July 2009. The Max White Effect on The Gray World White-Balancing Algorithm, *Proc. of the Visualization, Imaging and Image Processing Conf., VIIP, Cambridge, UK*, 237-242.