

Human computer interactions for converting color images to gray

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ABSTRACT

A classical image processing problem is converting color images to gray. This paper presents a Virtual Luminance Axis (VLA) to provide users a friendly interface to control the conversion process. The user selects several interesting color regions by drawing a few brush strokes, and then tunes the maximum and minimum of the corresponding band for each kind of color on the VLA. Our algorithm derives global mapping of the color space onto the VLA as close as possible. In this way, the user can “tune” the resulting image to produce the ideal effects he desires. Quantization and interpolating techniques are employed to accelerate the computation. The experiments show that the final gray is transferred as user defines.

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1. Introduction

Due to the cost of color printing, most publishers still prefer black and white. Usually it frustrates the authors when their vivid color pictures lost attractiveness after converted to grayscale image. Even worse, it is very difficult to find a general approach to preserve the details conveyed by colors after conversion. In addition, color-to-gray [3,11] is important for biometrics, e.g., face recognition and detection [15,5,6,13,14,17] and image processing, e.g., image retrieval and cartoon image description [2,19,1,12,16]. In this paper, we investigate an interactive solution to this problem with user's assistance in each specific case.

In traditional color-to-gray solutions, each color is mapped onto the luminance axis directly because the luminance is always the dominant information that human's optic organ receives.

However, in some cases, such simple method does not generate satisfactory result. Different colors may be transferred onto the same gray level, which makes them undistinguishable from each other (Fig. 1b). To tackle this problem, several algorithms [4,10,9,8] have been proposed in recent years.

Gooch et al. [4] presented an innovative method for color removal with salient details preservation. They defined a parameter θ to determine the colors' order, and two other parameters to control the contrast range of different colors and the neighborhood size for estimation. By tuning these three parameters, their

algorithm could give the visual features missing in the traditional color-to-gray method. Gooch's algorithm had a time-consuming problem for images with high resolution even with GPU acceleration. Ruzon et al. [10] settled this problem by adopting color clustering to implement the color quantization and then interpolating the grayscale value using look-up table.

Rasche et al. [9] built an MDS model to preserve global perceptual distances in CIE $L^*a^*b^*$ color space. To keep the luminance consistency, constraints were introduced to match their luminance order. The paper utilized the method known as “majorization” to optimize the STRESS function. The results showed that the gamut was mapped into high dynamic grayscale with the visual details maintained well. Rasche et al. [9] also exhibited some applications of re-coloring to preserve the image information for color-deficient viewers.

In [4], authors derived a framework based on the gradient domain to impose constraints on the entire set of contrasts in an image. Their framework gave a more efficient approach to solve color-to-gray conversation. They considered the close neighborhood on finer levels while far neighborhood on coarser levels, and achieved the images of similar quality as Gooch's with lower costs.

Nevertheless, such techniques mentioned above did not work all the time to convey enough visual information. Especially, they did not provide an intuitive interface to determine what kind of color to be lighter or darker. In this paper, a tightly integration is adopted to provide the user an easy controllable tool for image generation. A virtual luminance axis is proposed to model the mapping between the color and luminance.

Then, the color-to-gray process is formulated into a optimization problem, which can be solved easily by a linear system.

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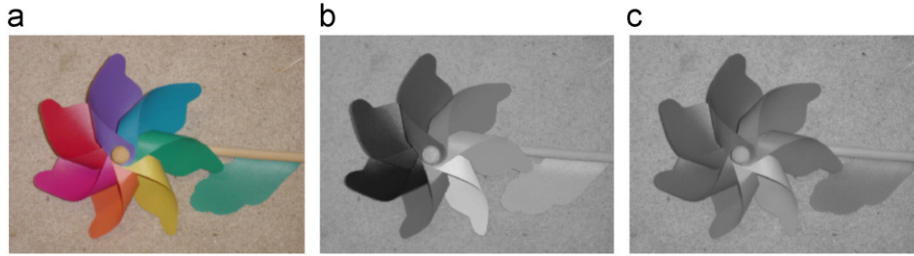


Fig. 1. Original color image (a), and the comparison of Photoshop's grayscale module (b) and our algorithm (c).

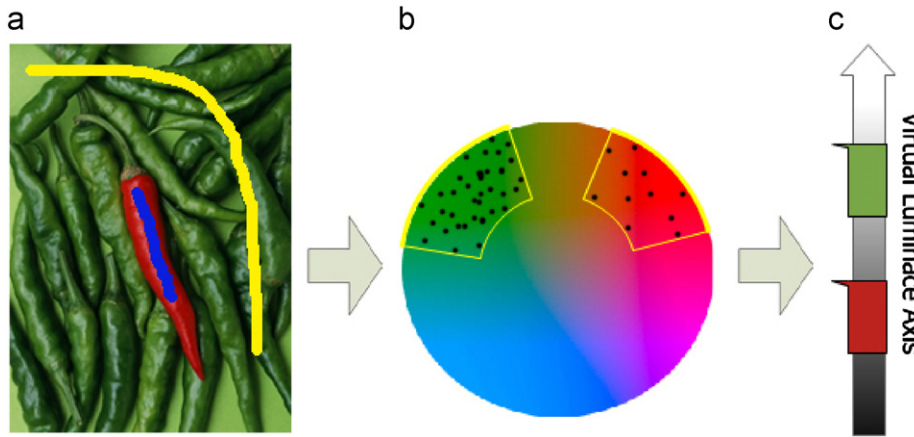


Fig. 2. The interactive procedure in the pepper example. (a) The original image superimposed with two brush strokes. (b) The boundaries of two color blocks in the chrominance plane are generated from the strokes. (c) The two bands on the VLA, which correspond to the green and red blocks respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Interactive color-to-gray

Most computations in our algorithm are performed in CIE $L^*a^*b^*$ color space because of the close correspondence between the Euclidean distances and perceptual dissimilarity in this color space [18].

Here we take two different views to see how our interactive color-to-gray works (Fig. 2).

From the user's view, he draws different color regions of interest with different brush strokes in the color image. Each kind of strokes should cover its color category as fully as possible. Then every color category has its corresponding band on the VLA, the user can tune the maximum and minimum of the bands to enforce his requirement. For the pepper example, if the user tunes the green band up, the grayscale of all green regions will increase.

From the computer's view, we calculate the statistics of the pixel colors covered by the brush strokes, and then determine the boundaries of the color categories on the chrominance plane. Guided by the boundaries, we break up the CIE $L^*a^*b^*$ color space into several parts, which we call "blocks". Next the target differences are specified in order to balance the original luminance differences and the pairwise bands' virtual differences on the VLA. The final grayscale differences are expected to closely match the corresponding target differences, so finally a quadratic function is optimized to retrieve the new grayscale configuration of the color image.

Quantization and interpolating technique is employed for acceleration. Those colors selected by quantization are called "landmark colors". We manipulate the landmark colors instead of all the pixel colors in the actual calculation.

2.1. User interface design

2.1.1. Color region selection

As the first step, we require the user label the color regions using the brush strokes. Each kind of strokes represents a color

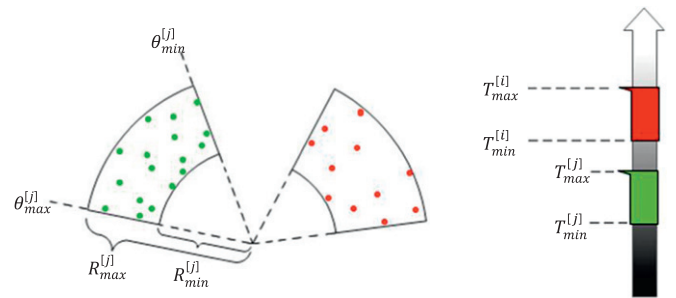


Fig. 3. (Left) To sector shapes in the chrominance plane, which are parameterized by the four variables. (Right) The simple two band example without intersection.

category. Healey and Enns [7] presented a method to divide the chrominance plane into ten categories with user-chosen name. Inspired by their result of category boundaries, we applied the sector shape to approximate the boundaries of color categories.

As Fig. 3 shown, all the pixel colors are covered by one kind of strokes are projected on the chrominance plane, and they are denoted belonging to color category j . Then we run through those points to obtain the maximum and minimum of the angle θ and radius R in the plane, similar to the definitions of hue and saturation in the HSV color model. The sector shape formed by the four parameters is assumed as the color category's boundary.

In the color manipulation process, it is necessary to avoid the intersection between the sectors. And if the overlapping situation occurs, we would like to split the overlapped region to set the boundary for each other.

According to the boundaries of color categories, we can break the CIE $L^*a^*b^*$ color space into several blocks. The set of all the landmark colors in the i -th block is denoted as C_i . The x -th landmark color within one sector would belong to the color block

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