Recoding Color Transfer as a Color Homography

Han Gong[1]
http://www2.cmp.uea.ac.uk/~ybb15eau/
Graham D. Finlayson[1]
g.finlayson@uea.ac.uk
Robert B. Fisher[2]
http://homepages.inf.ed.ac.uk/rbf/

[1] School of Computing Sciences
University of East Anglia
Norwich, UK

[2] School of Informatics
University of Edinburgh
Edinburgh, UK

The recently discovered color homography theorem proves that colors across a change in photometric viewing condition are related by a homography [2]. In this paper, we propose a color-homography-based color transfer decomposition which encodes color transfer as a combination of chromaticity shift and shading adjustment. Our experiments show that the proposed color transfer decomposition provides a very close approximation to many popular color transfer methods. We believe that our color transfer model is useful and fundamental for developing simple and efficient color transfer algorithms. Our model also enables users to amend the imperfections of a color transfer result or extract a concise form of the original desired effect (which allows a more efficient re-application of the original color transfer).

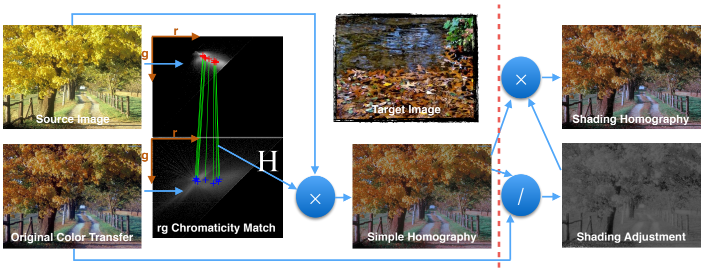

Figure 1: Pipeline of color-homography-based color transfer decomposition. The red dashed line divides the pipeline into two steps: 1) *Simple* homography. The rg chromaticities of the source image and the original color transfer image are matched according to their chromaticity locations (*e.g.* the green lines), from which we estimate a color homography matrix H and use H to transfer the source image. 2) *Shading* homography. The shadings are aligned between the *simple* homography result and the original color transfer result by a least-squares method. The per-pixel product of the *simple* homography result and the shading adjustment gives a close color transfer approximation.

In Figure 1, we start with the outputs of the prior-art algorithms. Assuming we relate source image I_s to target image I_t with a pixel-wise correspondence, we represent the RGBs of I_s and I_t as two $n \times 3$ matrices A and B respectively where n is the number of pixels. These $n \times 3$ matrices can be reconstituted into the original image grids. The chromaticity mapping is modeled as a 3×3 linear transform but because of the relative positions of light and surfaces there might also be per-pixel shading perturbations. Assume the Lambertian image formation is an accurate physical model,

$$DAH \approx B \tag{1}$$

where D is an $n \times n$ diagonal matrix of shading factors and H is a 3×3 chromaticity mapping matrix. A color transfer can be decomposed into a diagonal shading matrix D and a homography matrix H. The homography matrix H is a global chromaticity mapping. The matrix D can be seen as a change of surface reflectance or position of illuminant. Equation 1 can be solved by Alternating Least Squares [2]. To apply the extracted color transfer effect to a different scene, the shading adjustment D is further modeled as a smooth brightness-to-shading function f as follows:

$$\mathbf{diag}(D) \approx f(\mathbf{brightness}(AH)) \tag{2}$$

which is denoted by Mapped Shading Homography.

We show some visual results of color transfer approximations in Figure 2. Global 3D affine mapping [3] does not well reproduce the shading adjustments of color transfer. In Figure 3, the original shading homography approximation retains the artifacts of noise and over-saturation of the original color transfer result. These artifacts are fixed by mapped *shading* homography. Traditional color transfer methods cannot be directly applied to video color grading as per-frame color matching leads to temporal incoherence [1]. The color homography model is a concise representation of the original complex video color grading adjustments. Compared with a prior art [1], our model generates stable results in one-go without the excessive steps for removing artifacts such as flickering and bleeding. As shown in Figure 4, the complex steps of video color grading can be extracted as a simple mapped *shading* homography transfer which can also be re-applied to a different video sequence of a similar color theme.

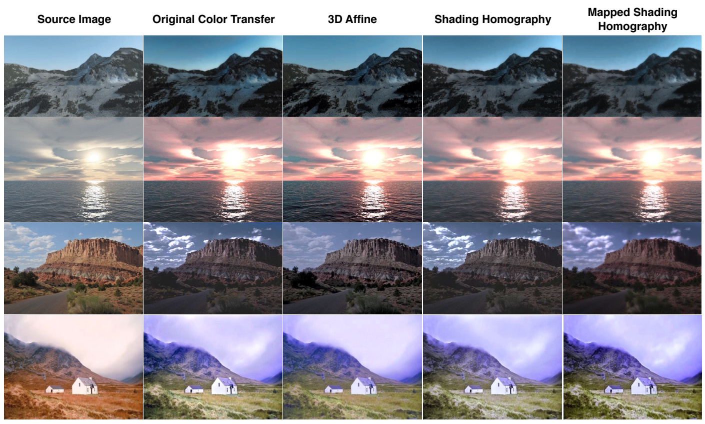

Figure 2: Visual result of color transfer approximations. Our homography-based methods produce closer approximations to the original color transfer results.

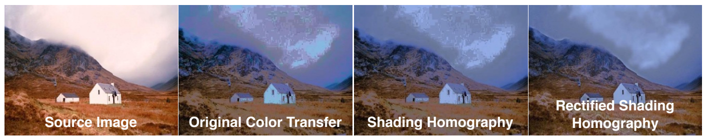

Figure 3: Imperfection fixing. The imperfections in a color transfer is fixed by mapped shading adjustment.

Figure 4: Video color grading re-application (original video from Cry ©Jeffro). The color grading profile is extracted from two pairs of image samples. Grading profile 1 is applied to the same scene. Grading profile 2 is applied to a scene different from its image samples.

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[3] F Pitié and A Kokaram. The linear monge-kantorovitch linear colour mapping for example-based colour transfer. In *European Conference on Visual Media Production*, pages 1–9. IET, 2007.