Efficient and Robust Color Consistency for Community Photo Collections

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Abstract

We present an efficient technique to optimize color consistency of a collection of images depicting a common scene. Our method first recovers sparse pixel correspondences in the input images and stacks them into a matrix with many missing entries. We show that this matrix satisfies a rank two constraint under a simple color correction model. These parameters can be viewed as pseudo white balance and gamma correction parameters for each input image. We present a robust low-rank matrix factorization method to estimate the unknown parameters of this model. Using them, we improve color consistency of the input images or perform color transfer with any input image as the source. Our approach is insensitive to outliers in the pixel correspondences thereby precluding the need for complex pre-processing steps. We demonstrate high quality color consistency results on large photo collections of popular tourist landmarks and personal photo collections containing images of people.

1. Introduction

Nowadays, the growing popularity of photo sharing and social networks makes it easy to crowdsource photo collections of popular locations and social events. This has led to applications ranging from virtual tourism and navigation [35], image completion [19], colorization [7] and photo uncropping [32]. However, the color statistics of each image in the collection could differ due to different scene illumination at capture time or due to different non linear camera response functions [15, 25]. Such photometric inconsistencies cause visual artifacts in applications that require seamless alignment of multiple overlapping images.

Although modern image editing packages provide some color correction, and tone adjustment functionalities, these techniques usually require indirect user interaction [2, 20], or direct adjustment of color balance or manipulation of the tone curve. Consequently, these interactive techniques are too tedious for large image collections. On the other hand, individual color correction is likely to produce images with inconsistent colors across the whole collection. Recently, HaCohen et al. [17] proposed a method to optimize color consistency across an image collection with respect to a reference image that relies on recovering dense pixel correspondence across multiple images [16]. This method is computationally expensive and not ideal for processing large collections involving thousands of images.

In this paper, we present a new matrix factorization based approach to automatically optimize color consistency for multiple images using sparse correspondence obtained from multi-image sparse local feature matching. For rigid scenes, we leveraging structure from motion (SfM) although it is an optional step. We stack the aligned pixel intensities into a vector whose size equals the number of images. Such vectors are stacked into a matrix, one with many missing entries. This is the observation matrix that will be factorized. Under a simple color correction model, the logarithm of this matrix satisfies a rank two constraint under idealized conditions (perfect correspondences, no noise, constant illumination). The rank two matrix can be expressed as a sum of two rank one matrices – one that depends on the color correction parameters and another that depends on the albedos of the scene points associated with the sparse correspondences. The color correction parameters can be viewed as pseudo white balance and gamma correction parameters of the image. Here, *pseudo* indicates that the estimates do not necessarily coincide with the ground truth values.

Our method is based on the low-rank matrix factorization technique proposed in [4] that is robust to outliers. Robustness is key to the success of our method since in real conditions, several factors – lighting change, shadows, saturated pixels, incorrect feature correspondences, etc. produce outliers that corrupts the low rank structure of the observation matrix. We also analyze ambiguities in the matrix factorization formulation and suggest ways to resolve them practically. The low rank matrix formulation and the application of the L_1-norm based robust factorization technique are the main contributions of our work.

Unlike the previous quadratic optimization problem formulation [17] which relies on dense and accurate correspon-

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