L2 based Colour Correction for Light Field Arrays

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1 Introduction

In recent years, there has been an increase in the popularity of Light Field (LF) imaging technology with the increase in availability of LF camera devices such as the Lytro, as well as an increase in the use of LF camera arrays [5]. However, both camera arrays and LF cameras can create views that exhibit colour discrepancies, and previous work has already tackled similar issues when data is captured using the Lytro camera [4] or multi-view camera systems [3]. In [4], an $\mathcal{L}_2$ based colour transfer method is applied in an iterative approach to recolour the views of a Lytro light field to correct the colour fading that occurs on outer views of the LF. This method was based on earlier $\mathcal{L}_2$ based methods proposed by Grogan et al.[1, 2]. In this paper, we propose to combine similar aspects of the $\mathcal{L}_2$ based cost function proposed in [1] with some of the cost function constraints proposed in [2], and propose a new propagation scheme so that this $\mathcal{L}_2$ based framework can be extended to colour correcting LF arrays. We also take advantage of a colour chart captured in the scene to not only ensure that colours are consistent across the LF, but also match the ground truth colour chart.

2 Estimating the Colour Transfer Function

For a target and palette image with colour correspondences $\{\mu_t^{(k)}, \mu_p^{(k)}\}_{k=1..n}$ (i.e. colours that should correspond after the colour correction function is applied to the target image), we propose the following cost function to register the colour distributions of the images:

$$\mathcal{C}(\theta) = \sum_{k=1}^{n} \frac{1}{n^2} \mathcal{N}(0; \phi(\mu_t^{(k)}, \theta) - \mu_p^{(k)}, 2h^2 \mathrm{I}) + \mathcal{E}(\phi(\mu_t^{(k)}, \theta)) \quad (1)$$

Here, the colour correction function ϕ is a thin plate spline function controlled by the parameter to be estimated, θ. The matrix I is the identity and h a parameter controlling the variance. The first term of this cost function computes the distance between two Gaussian Mixture models (GMMs) that model the color distributions of the transformed target and palette images respectively [1]. The error term $\mathcal{E}(\phi(\mu_t^{(k)}, \theta))$ is that proposed in [2] penalising transformed colour values that lie outside the RGB cube. The function ϕ estimated using Eq 2 therefore ensures the colour correspondences are accounted for during the optimisation and the amount of colours mapped outside of the RGB cube is minimised, while the thin plate spline function ensures a smooth colour correction function is estimated.

3 Recolouring the Light Field

To recolour the entire light field, each view is recoloured one by one starting with the centre view. To recolour the centre view I_c, the colour chart is extracted from the view and its 24 colours $\{x_c^{(k)}\}_{k=1..24}$ computed. Taking the corresponding 24 ground truth colour chart colours $\{x_g^{(k)}\}_{k=1..24}$, we define the correspondences $\{\mu_t, \mu_p\} = \{x_c, x_g\}$. We then minimise Eq. 2 to compute the colour correction function ϕ. The function ϕ is applied to all pixels in the centre view creating the recoloured view $\bar{I}_c$ (see Fig. 1).

When the centre view has been recoloured, all other views in the light field can then be corrected. For a view I_m, not only are the colour chart colours used to create correspondences $\{x_m, x_g\}$, but we also compute SIFT correspondences $\{s_m, s_{\bar{c}}\}$ between the view I_m and the recoloured centre view $\bar{I}_c$. Then, we define $\{\mu_t, \mu_p\} = \{x_c, x_g\} \cup \{s_m, s_{\bar{c}}\}$ and compute the function ϕ using Eq. 2 (see Fig 1).

4 Implementation and Results

The colour transfer functions are computed in RGB space. The LF views are captured in .exr format, and the transfer functions ϕ are converted to look up tables so they can be applied using software such as photoshop. We also found that if the camera colour parameters do not change across a video sequence, the transfer function ϕ estimated for each camera can be applied to all frames of a video captured using the same setup.

Our recoloured light field can be seen in Fig. 1. From this image, it's clear that our method successfully corrects any colour inconsistencies in the LF, as well as ensuring the colours of the colour chart match those of the ground truth. Quantitiatively, our method significantly improves the average MSE value between each view and the centre view from 813.5 before recolouring to 610.2 afterwards, as well as that computed between the captured and ground truth colours charts, which was 832.8 before recolouring and 81.3 afterward. Removing the SIFT correspondences and using only the colour chart information for all views when estimating the transfer functions reduces the MSE from 813.5 to only 698.5, highlighting that these additional correspondences between views provide significant improvement to the colour consistency of the lightfield.

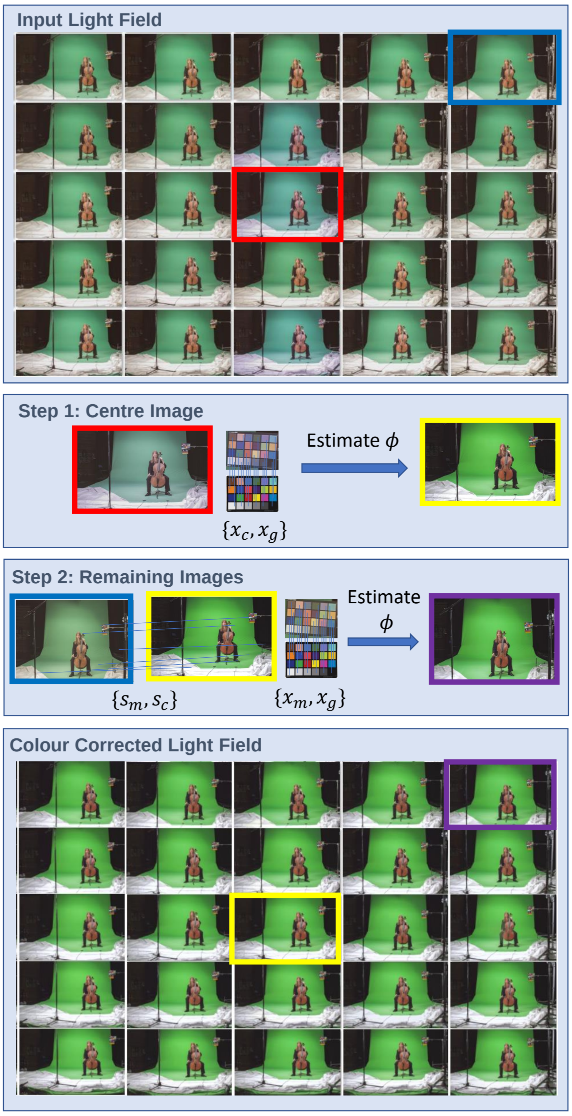

Figure 1: Our colour propagation approach for light field arrays.

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