Palette-based color harmonization

Jianchao Tan, Jose Echevarria, Yotam Gingold

I. Video Harmonization

Conceptually, our methods can naturally extend to video by simply applying our proposed harmonization approach to each frame independently. However, because the extracted palettes are optimized for the color distribution of each frame, temporal coherence is not guaranteed. To achieve that, we propose to first compute a global palette for the entire sequence of frames in a shot. To compute a global palette, we seek to compute the RGB-space convex hull of all frames' pixels together. To obtain this efficiently, we compute the convex hull for each frame independently, and then compute the global convex hull of all frames' convex hull vertices. Then we use the same convex hull simplification algorithm as Tan et al. [4] to obtain our global palette P^g to be harmonized. For the harmonization, we need to estimate the weight $W(P^g_j)$ of each color j of the global palette. For that, we apply the decomposition approach of Tan et al. [4] to each frame independently using the palette P^g. This gives us mixing weights for each color. We accumulate these mixing weights across all frames for each palette color P^g_j to obtain its total weight. With the global palette colors and weights, we can apply our harmonization method on the global palette to get a harmonized palette. Each frame is then harmonized according to the new colors and with the frame-specific mixing weights. We describe the overall video harmonization pipeline in Algorithm 1. Figure 1 shows examples of video harmonization. Complete videos can be found in the supplementary material. This approach could be extended to time-varying palettes [2]. Recoloring is real-time, since it is based on the same fast linear mixing approach we use for images [4]. However, it is not incremental, since we compute the global palette based on all frames' pixels. Just as with images, color harmony is often in tension with "naturalness."

Fig. 1. Video harmonization results. First and last frames are shown for each sequence, along an intermediate one to appreciate changes in color palette over time. Consistent harmonization is achieved across all of them.

II. Color Transfer

Our harmonic template framework enables new approaches to color transfer. Harmonic templates carry important information about the color distribution in a palette or an image. We propose to transfer that information between palettes and images.

a) Template alignment: Given an input image I and a reference image R, we already know how to extract their palettes P^I and P^R, and estimate their optimal templates, $T_I(\alpha^*_I)$ and $T_R(\alpha^*_R)$. After the fitting, we can compute the weight of each axis of the template as the sum of the weights of each color $W(P_i)$ assigned to it. With this, we have an estimate of the main axis for each template—the one with the greatest influence on the image. This simple procedure helps to establish a straightfoward match between palettes, something we can leverage to find the global rotation γ that aligns T_I with T_R. Next, we apply γ to globally rotate the colors of P^I and then we harmonize them with the target's template $T_R(\alpha^*_R)$ with $\beta = 1$. This method achieves results where I is recolored so it is harmonic with respect to R, taking into account the overall relevance of each color of the palette. Figure 2 shows results of this approach. We found that this method is good for matching dominant colors, which works better for content without real reference colors (e.g. graphics design or man-made objects).

b) Template transfer: When the final results should preserve better the original colors, a more conservative method can be formulated. In this case, we harmonize the input image colors P^I directly to the the best-fitting template for the reference image $T_R(\alpha^*_R)$, without any global rotation. We match palette colors to template axes according to Equation 1.After changing the hues of P^I with any of the proposed methods, we attempt to match lightness and chroma between palettes by scaling the lightness and chroma of each palette color to that the average L/C of the input and reference palette colors match. Figure 2 shows results from this method. We compare both color transfer approaches with previous work in Figure 3.

References

[1] B. Arbelot, R. Vergne, T. Hurtut, and J. Thollot. 2016. Automatic Texture Guided Color Transfer and Colorization. In *Proceedings of the Joint Symposium on Computational Aesthetics and Sketch Based Interfaces and Modeling and Non-Photorealistic Animation and Rendering* (Lisbon, Portugal) *(Expresive '16)*. Eurographics Association, Aire-la-Ville, Switzerland, Switzerland, 21–32. http://dl.acm.org/citation.cfm?id=2981324.2981328

Algorithm 1: Our proposed video harmonization process.

Input: Original video frames F, frame number N and harmonization template T

Output: Harmonized video frames H.

// Aggregate dense convex hull vertices of each frame F_i
$i \leftarrow 0$
$I \leftarrow \emptyset$
while $i < N$ **do**
    $I \leftarrow I \cup$ ConvexHull ($\mathbf{F_i}$)
    $i \leftarrow i + 1$
end
// Extract the global palette of the video sequence
$P_{original} \leftarrow$ Simplify(ConvexHull($\mathbf{I}$))
// Get averaged mixing weights for the global palette
$i \leftarrow 0$
$W_{sum} \leftarrow \mathbf{0}$
while $i < N$ **do**
    $W_i \leftarrow$ LayerDecomposition(F_i , $P_{original}$)
    $W_{sum} \leftarrow W_{sum} + W_i$
    $i \leftarrow i + 1$
end
$W_{avg} \leftarrow W_{sum}/N$
// Harmonize the global palette
$P_{harmonized} \leftarrow$ Harmonize($P_{original}$, W_{avg}, T)
// Recolor frames with the harmonized palette
$i \leftarrow 0$
while $i < N$ **do**
    $H_i \leftarrow W_i \cdot P_{harmonized}$
    $i \leftarrow i + 1$
end
return H

[2] Zheng-Jun Du, Kai-Xiang Lei, Kun Xu, Jianchao Tan, and Yotam Gingold. 2021. Video Recoloring via Spatial-Temporal Geometric Palettes. *ACM Transactions on Graphics (TOG)* 40, 4, Article 150 (jul 2021), 16 pages. https://doi.org/10.1145/3450626.3459675

[3] François Pitié, Anil C. Kokaram, and Rozenn Dahyot. 2007. Automated Colour Grading Using Colour Distribution Transfer. *Comput. Vis. Image Underst.* 107, 1-2 (July 2007), 123–137. https://doi.org/10.1016/j.cviu.2006.11.011

[4] Jianchao Tan, Jose Echevarria, and Yotam Gingold. 2018. Efficient palette-based decomposition and recoloring of images via RGBXY-space geometry. *ACM Transactions on Graphics (TOG)* 37, 6, Article 262 (Nov. 2018), 10 pages. https://doi.org/10.1145/3272127.3275054

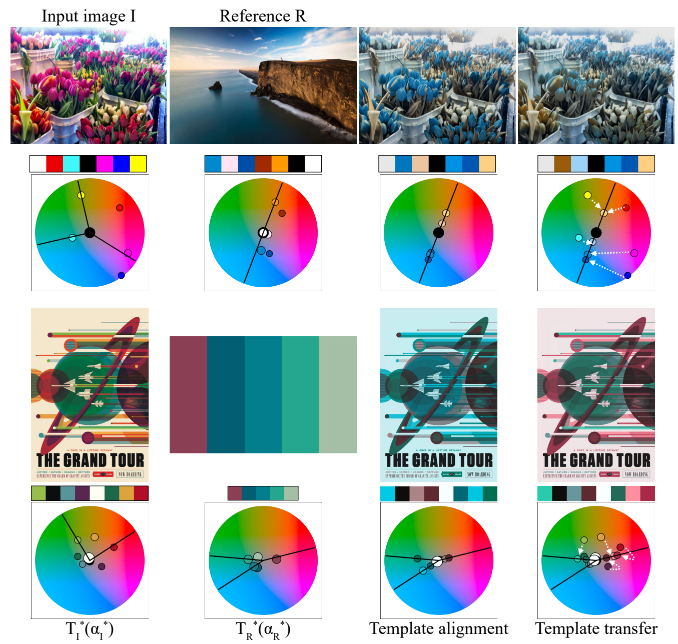

Fig. 2. Comparison between our two template-based color transfer methods. Third column shows how aligning the input and reference templates, $T_I^*(\alpha_I^*)$ and $T_R^*(\alpha_R^*)$ respectively, transfers better the overall color proportions, something that tends to work better for content without critical color semantics (bottom example). On the other hand, template transfer (rightmost column), preserves better the original colors.

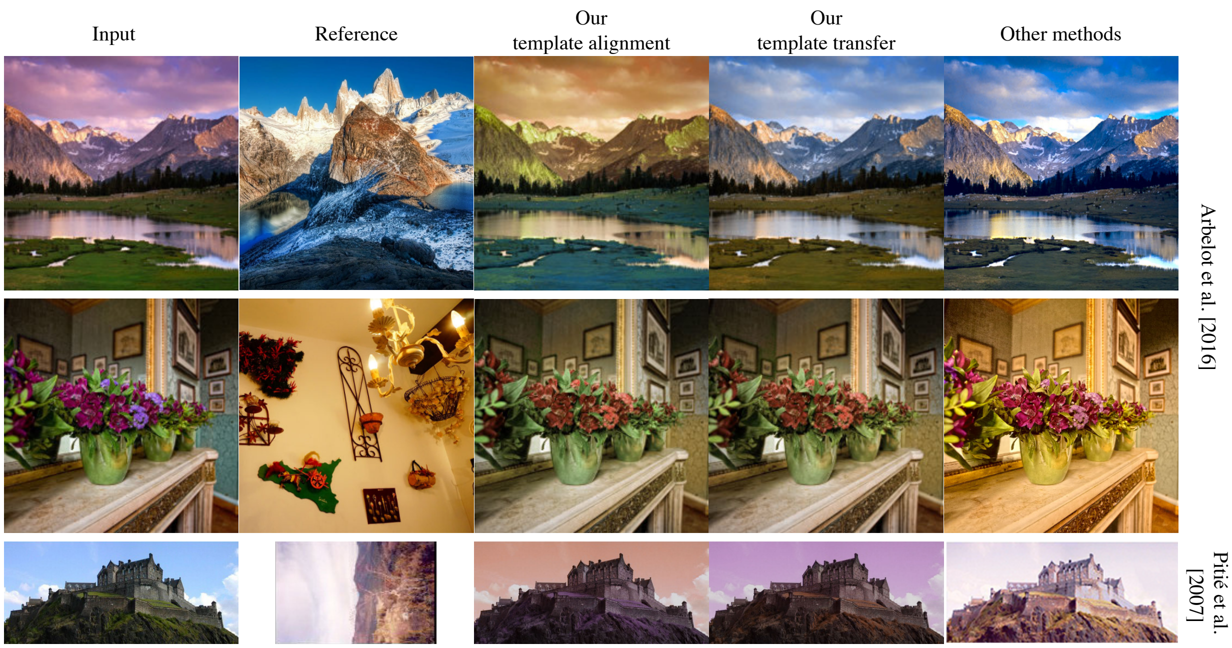

Fig. 3. Color transfer comparison with some previous works: Arbelot et al. [1] (first and second rows) and Pitié et al. [3] (bottom row). From left to right: input image, reference, template alignment, template transfer and the related works. Our methods provide some results closer to Arbelot et al. [1], especially template transfer (column 4). Compared to Pitié et al. [3], our transfers do not capture the overall tone that well, but produce usable stylized results.