Cluster-Based Color Space Optimizations

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**ABSTRACT**

Printing, displaying, and visualizing images are common tasks that may require a transformation of the input image from its source color space to a target color space. Such transformations include converting color images to grayscale for printing, mapping images to the gamuts of target display devices, and fusing multispectral data into a tristimulus image. Each of these transformations has a straightforward, standard mapping, often involving information loss. In the extreme case, contrast is completely lost when different colors in the source space map to the same color in the target space, an effect known as metamerism.

We present a framework for mapping an image from a source color space to a target color space in a way that preserves as much of the local contrast from the source image as possible while staying as faithful as possible to the standard mapping. Our unified framework is a cluster-based approach which we apply to a variety of color space transformations including color to gray conversion, color gamut mapping, image optimization for color deficient viewers, and multispectral image fusion.

**METHOD OVERVIEW**

1) Projection to target space. project source image to target space
2) Clustering. cluster pixels in spatio-chromatic space
3) Graph creation. connect spatially close clusters
4) Optimization. solve for new cluster colors, preserve local contrasts
5) Blending. transfer results back to pixels

**PROJECTION TO TARGET SPACE**

- project source image to target space using standard mapping
- get initial mapped image whose contrast we aim to enhance

**COLOR TO GRAY CONVERSION**

preserves chromatic contrast

**GAMUT MAPPING**

preserves out-of-gamut details

**IMAGE OPTIMIZATION FOR COLOR DEFICIENT VIEWERS**

preserves contrast within viewer’s space of distinguishable colors

**MULTISPECTRAL IMAGE FUSION**

visible + near-infrared fusion

**BLENDING**

- calculate output pixels using weighted blend of cluster translations
- weights are inversely proportional to squared Mahalanobis distance

**OPTIMIZATION**

- solve for new cluster colors \(x\)

\[ x = \arg \min_x E_T + w E_M \]

- target term \(E_T\): preserve local contrasts

\[ E_T = \sum_{i,j \in E} |\tau_{ij} | (x_i - x_j - a_{ij})^2 \]

- \(a_{ij} = k \cdot S(y_j)(a_{ij} - \|f(m_i) - f(m_j)\|)\)

- regularization term \(E_M\): stay close to standard mapping

\[ E_M = \sum_{i \in V} \tau_i (x_i - m_i)^2 \]

- additional terms:
  - hue term: preserve hue by minimizing deviations from constant hue plane
  - achromatic term: preserve neutrality of achromatic colors by minimizing deviations from gray axis

- constrained optimization for arbitrary-shaped target spaces: solve for colors, project to target space, iterate

**GRAPH CREATION**

vertices \(V\): clusters

edges \(E\): connect spatially close clusters, represent local contrasts between neighboring clusters

**CLUSTERING**

- cluster pixels in spatio-chromatic space \(U\) to get areas that may exhibit local contrast

\[ u \in U \Rightarrow u = (u', y'), s = \{\text{pixel color}, (u', y')\} = \text{weighted spatial dimensions} \]

- kmeans clustering

**MULTIPRIMARY IMAGE FUSION**

multiprimary image fusion

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