REGION-BASED COLOR TRANSFER FROM MULTI-REFERENCE WITH GRAPH-THEORETIC REGION CORRESPONDENCE ESTIMATION

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Introduction

- Color transfer
  - To transfer color characteristics from reference image(s) to a target image
- Motivation
  - Automatically transferring color from multi-reference
  - Incorporating spatially adjacent relationships to determine the best-matched region pair
    - Graph-theoretic region correspondence estimation

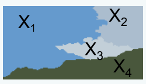
- Related work
  - Global color transfer [Reinhard et al. 2004]
    - The whole image is treated as a single entity
    - Ineffective to images with complex content
    - Depending on the similarity between reference and target
  - Local color transfer
    - Conducting color transfer for each region [Tai et al. 2005]
    - Using multi-reference [Xiang et al. 2008]
    - The best-matched reference region is determined in terms of only color distributions

Graph theoretic region correspondence estimation

- Preprocessing
  - Selecting reference images by CBIR [Li and Hsu 2008]
  - Mean-shift region segmentation
- Modeling [Li and Hsu 2008]
  - Representing each image as an attributed graph

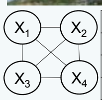
$G_T = (V_T, E_T, \mathbf{T})$ target

$G_S^i = (V_S^i, E_S^i, \mathbf{S}^i)$ the i-th reference



  - Adjacency matrix

$$T_{ab} = \begin{cases} \mu_{ab}, \text{ if } (x_a, x_b) \in E_T \\ 0, \text{otherwise} \end{cases}$$



	X_1	X_2	X_3	X_4
X_1	0	0.86	0.77	0.02
X_2	0.86	0	0.97	0.02
X_3	0.77	0.97	0	0.22
X_4	0.02	0.02	0.22	0

※ Edge weight: $\mu_{ab} \propto \exp\{-d(x_a, x_b)\}$

- Region mapping function

$$f(x_a, y_m^i) = \exp\{-(d(x_a, y_m^i) + w_{am}^i)\}$$

  - The neighboring dissimilarity between x_a and y_m^i

$$w_{am}^i = \sum_{b=1}^{|V_T|} \sum_{n=1}^{|V_S^i|} T_{ab} S_{mn}^i \, d(x_b, y_n^i)$$

  - A weighted sum of distance between all neighboring regions
  - Insensitive to different segmentation results

- Determining the best-matched region $\{(x_a, y_{m^*}^{i^*}) | x_a \in V_T\}$

$$m^*, i^* \leftarrow \arg\max_{m,i} \{ f(x_a, y_m^i) | 1 \le i \le K \}$$

※ m* is the best-matched region and i* is its corresponding image

Automatic color transfer

- Color transfer procedure for each pixel z
  - Chromatic channels

$$\tilde{\alpha}_z = \frac{\sigma^{\alpha}_{y_{m^*}^{i^*}}}{\sigma^{\alpha}_{x_a}} (\alpha_z - \mu^{\alpha}_{x_a}) + \mu^{\alpha}_{y_{m^*}^{i^*}} \qquad \tilde{\beta}_z = \frac{\sigma^{\beta}_{y_{m^*}^{i^*}}}{\sigma^{\beta}_{x_a}} (\beta_z - \mu^{\beta}_{x_a}) + \mu^{\beta}_{y_{m^*}^{i^*}}$$

  - Luminance channel

$$\tilde{\ell}_z = \frac{\sigma_S^{\ell}}{\sigma_T^{\ell}} (\ell_z - \mu_T^{\ell}) + \mu_S^{\ell}$$

- Incorporating the idea of intrinsic component
  - Eliminating the effect of light changes
    - Estimating reflectance-related image ρ [Finlayson et al. 2004]
    - Replacing the edge weight with reflectance similarity

$$\mu_{ab} \propto \exp\{-d(x_a, x_b)\}$$

$$d(x_a, x_b) = \| \mu^{\rho}_{x_a} - \mu^{\rho}_{x_b} \|$$

  - Reducing color-bleeding artifact
    - Weighted color transfer procedure for each pixel z

$$\hat{\alpha}_z = \frac{r_z^{x_a} \tilde{\alpha}_z + \sum_{x_b \in \eta(x_a)} r_z^{x_b} \tilde{\alpha}_z^{x_b}}{r_z^{x_a} + \sum_{x_b \in \eta(x_a)} r_z^{x_b}} \qquad \tilde{\alpha}_z^{x_b} = \frac{\sigma^{\alpha}_{y_{n^*}^{j^*}}}{\sigma^{\alpha}_{x_b}} (\alpha_z - \mu^{\alpha}_{x_b}) + \mu^{\alpha}_{y_{n^*}^{j^*}}$$

∗ η(·): neighboring region
∗ Performing the same procedure in β channel

※ Reflectance-related weight

$$r_z^{x_{b'}} = \exp\left\{ -\frac{(\rho_z - \mu^{\rho}_{x_{b'}})^2}{2{\sigma^{\rho}_{x_{b'}}}^2} \right\}$$

Experimental results

- Performance measurement
  - Colorfulness dissimilarity △C [Xiang et al. 2008]
  - Entropy E

Original

[Reinhard et al. 2004]
ΔC=8.448, E=10.638

[Xiang et al. 2008]
ΔC=14.112, E=6.714

Mean-shift segmentation + [Xiang et al. 2008]
ΔC=7.459, E=8.084

Proposed
ΔC=1.2467, E=8.7124

- Quantitative measures over 100 test images

	[Reinhard et al. 2004]	[Xiang et al. 2008]	Proposed
Averaged ΔC	10.36	10.08	5.39
Average E	10.20	9.07	9.26

  - Both subjective evaluation and quantitative measures show that our proposed algorithm outperforms the previous work