Selective Color Transferring via Ellipsoid Color Mixture Map

Visual Communication and Image Representation
Vol. 23, No. 1, 2012
Shiguang Liu, Hanqiu Sun, and Xiang Zhang

Presented by Euiwon Nam

School of Electrical Engineering and Computer Science
Kyungpook National Univ.
Abstract

- Color transfer
  - Most of conventional methods
    • Complex for user interaction
    • Difficult image segmentation
  - Proposed method
    • Use of color transfer simply
      - Effective ellipsoid color mixture map
        » Realizing selective color transfer
    • Color mixture map
      - Blending weight of pixels in output image
        » According to color and distance information
Introduction

- Color transfer
  - Previous work for color transfer
    - Processing focused on global
      - Based on Reinhard’s method
    - Local color transfer
      - Segmentation and cluster in conventional methods
        » Using stroke to select area of interest
        » Unpractical for Non-professional
Proposed method

- Novel color transferring using ellipsoid color mixture map
  - Selective re-rendering color
    - Simple for user by window-click in source image
- Main contribution of proposed method
  - Ellipsoid hull
    - Expressing color statistics of images
    - Geometry analysis
      » Transform of ellipsoids as color transfer
  - Efficient performance for selective color transfer
    - Images and video sequences, locally or globally
  - Simple window-click interaction
    - Searching object of interest automatically for high-quality color transfer
Related work

- Previous methods
  - Global color transfer
    - Reinhard et al
      - Transferred color characteristics from source to target image
    - Welsh, Abadpour and Kasaei
      - Coloring grayscale image
    - Chang et al
      - Transferring colors based on basic color category
    - Pietie et al
      - Based on N-dimensional probability density function transfer
    - Neumann’s method
      - Transferring color style of source image into arbitrary given target image
    - Yang’s method
      - Allowing user for selecting color mood simply with mouse click
Local color transfer

• Tai et al
  - Probabilistic segmentation by expectation maximization
• Maslennikova
  - Prepared color-image influence map
• Luan et al
  - Developing interactive tool for local color transfer
• Wen et al
  - Stroke-based user interface for multiple local color transfers
• Xiang et al
  - New selective color transfer method using multi-source images
Selective color transferring

- Color transfer
  - Window-click of input simply
    - Indicating region of interest

Fig. 1. Result of selective color transfer via ellipsoid color mixture map.
Ellipsoid hull

- Novel means to express distribution of image pixels
  - New distribution of pixels

\[
e(i, j) = c(i, j) - \mu_L, \quad \mu_L = E(c_L(i, j))
\]  \hspace{1cm} (1)

where \((i, j)\) denotes pixel, \(c(i, j)\) is pixel values in source image or target image, 
\(e(i, j)\) represents pixel values in ellipsoid hull, 
\(c_L(i, j)\) is pixel value of selected area, 
\(\mu_L\) denotes mean value of selected area’s color which is center of ellipsoid hull, 
\(E\) represents expectation operation.
• Ellipsoid hull

Fig. 2. Sketch map of an ellipsoid hull.
• Length of major semi-principal axis of ellipsoid hull

\[ L = \sqrt{E((e_{-}R(i, j))^2 + (e_{-}B(i, j))^2)} \]  

where \( e_{-}R(i, j) \), \( e_{-}G(i, j) \) and \( e_{-}B(i, j) \) are the lengths from the pixel \((i, j)\) to the plane perpendicular to \( R \), \( G \) and \( B \) axes respectively.

• UVW system for facilitating standardization
  - Matching three axes of ellipsoid hull

If \( \phi_r = \phi_g = \phi_b \), then \( U = R, V = G, W = B \). Or else

\[
W = \begin{cases} 
R, & \text{if } \min(\phi_r, \phi_g, \phi_b) = \phi_r \\
G, & \text{if } \min(\phi_r, \phi_g, \phi_b) = \phi_g \\
B, & \text{if } \min(\phi_r, \phi_g, \phi_b) = \phi_b 
\end{cases} \quad V = \begin{cases} 
R, & \text{if } \max(\phi_r, \phi_g, \phi_b) = \phi_r \\
G, & \text{if } \max(\phi_r, \phi_g, \phi_b) = \phi_g \\
B, & \text{if } \max(\phi_r, \phi_g, \phi_b) = \phi_b 
\end{cases}
\]
• Correcting direction of rotation angles

\[
\theta = \begin{cases} 
\theta, & \text{if } \text{Cov}(U,V) \geq 0 \\
-\theta, & \text{if } \text{Cov}(U,V) < 0 
\end{cases}, \quad \theta_b = \begin{cases} 
\theta_b, & \text{if } \text{Cov}(U,V) \geq 0 \\
-\theta_b, & \text{if } \text{Cov}(U,V) < 0 
\end{cases}
\] (4)

where \( E \) represents expectation operation, \( \text{Cov}(U,V) \) is covariance of \( U \) and \( V \) axes.

• Rotations to standardize ellipsoid hull

\[
\begin{pmatrix} U' \\ V' \end{pmatrix} = \begin{pmatrix} \cos \phi_b & \sin \phi_b & 0 \\ -\sin \phi_b & \cos \phi_b & 0 \end{pmatrix} \begin{pmatrix} U'' \\ V'' \end{pmatrix}, \quad \begin{pmatrix} U'' \\ V'' \end{pmatrix} = \begin{pmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \end{pmatrix} \begin{pmatrix} U \\ V \end{pmatrix}
\] (5)

where \( U'V'W' \) indicates standardized ellipsoid hull, \( U''V''W'' \) is intermediate values used in our match rotating, which are derived using matrix operation on \( UVW \).
Generation of the intermediate image

- Generating intermediate image
  - Used for final color transferring

Fig. 3. Processing the river image: (a) intermediate image; (b) color mixture map.
– Shifting and scaling target ellipsoid hull
  • By taking into account source ellipsoid hull’s shape

\[
U_M' = \frac{a_S}{a_T} U_T', \quad V_M' = \frac{b_S}{b_T} V_T', \quad W_M' = \frac{c_S}{c_T} W_T',
\]  

(6)

where \( S, T \) and \( M \) mean source, target and intermediate image accordingly. \( U_M', V_M' \) and \( W_M' \) represent values of intermediate image in \( U'V'W' \) system, \( a_i, b_i \) and \( c_i \) (\( i = S, T, S \) and \( T \) represent source and target, respectively) are covariance of \( U', V' \) and \( W' \) respectively.

– Generation of intermediate image
  • By moving above distribution of pixel to origin of ellipsoid

\[
c_M(i, j) = e_m(i, j) + \mu_L
\]  

(7)

where \( c_M(i, j) \) denotes color of pixel \( (i, j) \) in intermediate image, \( e_m(i, j) \) is color value of pixel \( (i, j) \) of intermediate image in \( UVW \) system, \( \mu_L \) is mean value of selected area's color.
Color mixture map

- Pixel to origin of ellipsoid hull
  - Decreasing weight when distance increase
    \[
    m_1(i, j) = 2 - \exp\left( p \cdot \frac{d(i, j)}{N} \right)
    \]  
    \[(8)\]

- Calculating difference between selected area and global area
  \[
  m_2(i, j) = \begin{cases} 
    1, & \text{if } d(i, j) < R_{L,T} \\
    e^{-p(d(i, j)-R_{L,T})^2}, & \text{if } d(i, j) \geq R_{L,T} 
  \end{cases}
  \]
  \[(9)\]

where \(N\) is coefficient, \(d(i, j)\) indicates Euclidean distance from pixel \((i, j)\) to origin of target ellipsoid hull in \(UVW\) system, \(p\) is value computed by color purity of selected area and color difference between selected area and global area, \(R_T\) and \(R_{L,T}\) represent range of global area and selected area.
• Range of selected area and global area

\[ R_T = \sqrt{D(U_T) + D(V_T) + D(W_T)} \]  \hspace{1cm} (10)  
\[ R_{L,T} = \sqrt{D(U_{L,T}) + D(V_{L,T}) + D(W_{L,T})} \]  \hspace{1cm} (11)  

• Computed value by target image
  - Color purity and difference between selected and global area

\[ P = \frac{1}{R_{L,T} \cdot E((U'_T(i,j),V'_T(i,j),W'_T(i,j)))} \]  \hspace{1cm} (12)  

where \( D \) represents the standard deviation operator, \((U_T, V_T, W_T)\) and \((U_{L,T}, V_{L,T}, W_{L,T})\) are pixel coordinates in global and selected area of target, \((U'_T, V'_T, W'_T)\) represents values of target image in \(U'V'W'\) system, \(E\) is expectation operation.
– Final result of color transferring
  • Mixing intermediate and target image

\[
C_R(i, j) = C_M(i, j)m(i, j) + C_T(i, j)(1 - m(i, j))
\]

(13)

where \(C_R(i, j)\), \(C_M(i, j)\) and \(C_T(i, j)\) are colors of pixel \((i, j)\) in final, intermediate and target image, respectively.
Evaluation metric

- Comparing evaluation vectors
  - between final and source image

\[
\lambda = \begin{bmatrix}
Cov(U,V) \\
Cov(U,W) \\
Cov(V,W)
\end{bmatrix}, \quad \gamma = \frac{\lambda_s^T \cdot \lambda_T}{\| \lambda_s \| \cdot \| \lambda_T \|}
\]  

where \( Cov \) is covariance of two color axes.

\( \lambda_s \) and \( \lambda_T \) represent evaluation vector of source and final image,

\( \lambda_s^T \) is transpose of \( \lambda_s \).
SCT results

- Experimental tests of color transferring
  - SCT testing example of flower scene

Fig. 4. Our selective color transferring of a flower scene.
Comparison with previous work of color transfer

Fig. 5. Comparisons with the previous work (see the detail enlarged by the dotted lines).
– Comparison with previous work of color transfer

Fig. 6. Comparisons of user inputs by the previous work and ours.
- Variable window inputs and color mixture maps

Fig. 7. Testing of varying window inputs and the color mixture maps.
Video examples using SCT

(a) Video color transferring with flowers in wind

(b) Video color transferring with cars in grassland

(c) Video color transferring with dynamic magic box

Fig. 8. More video results using our SCT approach: top row shows target video, and second row shows final video (with corresponding frames).
– Parameters and rendering rates of image and video sequences

**Table 1.** Control parameters and rendering rates for SCT of images.

<table>
<thead>
<tr>
<th>Images</th>
<th>Size</th>
<th>$\phi_B(S)$</th>
<th>$\phi_B(T)$</th>
<th>$\theta(S)$</th>
<th>$\theta(T)$</th>
<th>$p$</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 1</td>
<td>1024 × 768</td>
<td>0.8471</td>
<td>0.8729</td>
<td>0.7163</td>
<td>0.7313</td>
<td>3.813E-4</td>
<td>2.68</td>
</tr>
<tr>
<td>Fig. 4</td>
<td>1024 × 1053</td>
<td>0.7832</td>
<td>0.9097</td>
<td>0.7660</td>
<td>0.7240</td>
<td>2.139E-4</td>
<td>2.89</td>
</tr>
<tr>
<td>Fig. 9(a)</td>
<td>1024 × 768</td>
<td>0.7118</td>
<td>0.8779</td>
<td>0.7111</td>
<td>0.6137</td>
<td>2.598E-4</td>
<td>2.44</td>
</tr>
<tr>
<td>Fig. 9(b)</td>
<td>1280 × 800</td>
<td>0.7017</td>
<td>0.8121</td>
<td>0.5153</td>
<td>0.6658</td>
<td>1.541E-4</td>
<td>3.23</td>
</tr>
<tr>
<td>Fig. 9(c)</td>
<td>1024 × 718</td>
<td>0.93766</td>
<td>0.87881</td>
<td>0.773</td>
<td>0.72488</td>
<td>1.626E-4</td>
<td>1.59</td>
</tr>
<tr>
<td>Fig. 9(d)</td>
<td>1190 × 924</td>
<td>0.9169</td>
<td>0.8861</td>
<td>0.7836</td>
<td>0.6792</td>
<td>1.216E-4</td>
<td>2.42</td>
</tr>
<tr>
<td>Fig. 10</td>
<td>964 × 720</td>
<td>0.5380</td>
<td>0.8736</td>
<td>0.6730</td>
<td>0.7672</td>
<td>1.2106E-4</td>
<td>0.34</td>
</tr>
</tbody>
</table>

**Table 2.** Control parameters and rendering rates for SCT of video sequences.

<table>
<thead>
<tr>
<th>Videos</th>
<th>Size</th>
<th>Frames</th>
<th>$\phi_B(S)$</th>
<th>$\phi_B(T)$</th>
<th>$\theta(S)$</th>
<th>$\theta(T)$</th>
<th>$p$</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 8(a)</td>
<td>1024 × 768</td>
<td>200</td>
<td>0.6369</td>
<td>0.8055</td>
<td>0.5580</td>
<td>0.7227</td>
<td>1.0229E-4</td>
<td>190.20</td>
</tr>
<tr>
<td>Fig. 8(b)</td>
<td>720 × 480</td>
<td>240</td>
<td>0.7911</td>
<td>0.8939</td>
<td>0.4886</td>
<td>0.7775</td>
<td>2.8055E-4</td>
<td>77.52</td>
</tr>
<tr>
<td>Fig. 8(c)</td>
<td>720 × 480</td>
<td>360</td>
<td>0.8061</td>
<td>0.4737</td>
<td>0.6793</td>
<td>0.6920</td>
<td>5.7556E-4</td>
<td>115.92</td>
</tr>
</tbody>
</table>
More re-color image examples

Fig. 9. More results using our SCT approach, from left to right: source image, target image, and final color-transfer result.
– Sun-set image example

(a) source image  (b) target image  (c) final result

**Fig. 10.** Sun-set example using our SCT approach, with the global effect.
Summary

- Novel and simple color transferring
  - Window-clicks
    - Computing related structures automatically
    - Selecting color to target image
  - Ellipsoid color mixture map
    - Users to selectively re-render colors
  - Extending selective color transfer for video
    - Processing other frame automatically after 1st fame