Memory color assisted illuminant estimation through pixel clustering

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Abstract

◆ Illuminant estimation
  – Need for assumption such as gray world theory
  – Inclusion of contents in most personal images
    • Neutral objects, human beings, sky, plants

◆ Proposed method
  – Estimating illuminant through the clustering of pixels of gray and three dominant memory color
    • Skin tone, sky blue, foliage green
  – Requirements
    • Spectral sensitivity response of the camera
    • Spectral database of the CIE standard illuminants
    • Reflectance of samples
Perception of color information

- Color constancy
  - Perceiving object colors under varying ambient light
Approach for color constancy

– Classification of estimation of illuminant
  • Statistical approach
    – Gray world algorithm, max RGB algorithm, database gray world algorithm, neutral networks, gamut mapping approach, Bayesian algorithm
  • Physics-based approach
    – Seeking to estimate the scene illuminant by exploiting the interaction between light and surfaces

– Proposed method
  • Illuminant estimation using memory colors
    – Assistance to detect illuminant using skin, sky, foliage colors
    – Segmentation of objects
    – Classification of objects according to the general range of the considered memory colors
    – Mapping the objects to center regions of the selected memory colors
The Method

Memory colors in real world images

- Majority of personal photos
  - Including at least one type of the following contents
    - Portraits, landscapes, and sky
- Use of three dominant memory colors for the purpose of illuminant estimation
  - Skin tone, foliage green, sky blue, and on top of gray
Memory color database

- Spectral database for memory color
  - Measurements of a large number of samples
  - Using references

Fig. 1. Left: spectral reflectance database of gray. Right: spectral reflectance database of skin.
– Spectral data for sky
  • Radiance instead of reflectance

Fig. 2. Left: spectral reflectance database of green. Right: spectral reflectance database of sky.
Image formation process formulated
  – Adopting a widely used simple linear model

\[ \zeta_k = \int E(\lambda) R(\lambda) S_k(\lambda) d\lambda \]  \hspace{1cm} (1)

  – For sky blue sample

\[ \zeta_k = \int E(\lambda) S_k(\lambda) d\lambda \]  \hspace{1cm} (2)
Memory color region modeling
- Using the spectral sensitivity data
  - Measurement from a commercial camera with raw image capture capability
  - Cluster of samples for each illuminant

Fig. 3. Left: chromaticity distributions of gray samples under a few CIE illuminants. Chromaticity distributions of skin samples under a few CIE illuminants.
- Assumption
  - Clusters have normal ellipsoidal distributions
  - Characterization of clusters by the center (mean) and axes
- Using the sensor RGB color space
  - Avoiding the difficulties in converting raw RGB data to other color space

Fig. 4. Left: chromaticity distributions of green samples under a few CIE illuminants. Chromaticity distributions of sky samples under a few CIE illuminants.
Color pixel classification

– Standard cluster analysis

• Using the maximum likelihood with a Mahalanobis measure
• Likelihood of a pixel with chrominance vector $c$ for a certain color

$$P(c) = \frac{1}{2\pi |\Lambda|^{1/2}} \exp \left[ -\frac{1}{2} \lambda^2 \right]$$

where $\lambda$ is the Mahalanobis distance whose definition is

$$\lambda^2 = (c - \mu)^T \Lambda^{-1} (c - \mu)$$

where $\mu$ is the mean vector,
$\Lambda$ is the covariance matrix.
Algorithm demonstration

– Environment

• Calibrated commercial camera with automatic exposure control
• Use of illuminants with D75, D65, D55, D50, F11, F6, CWF, A, and Horizon

Fig. 5. Example image with sky, skin, green, and gray.
– Detected color pixels

Fig. 6. Detected color pixels under D55.
– Summary of the color pixel classification of the example image

Table 1. Color pixel classification example (image size: 1512x2016).

<table>
<thead>
<tr>
<th></th>
<th>D75</th>
<th>D65</th>
<th>D55</th>
<th>D50</th>
<th>F11</th>
<th>F6</th>
<th>CWF</th>
<th>A</th>
<th>Horizon</th>
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<tr>
<td>Gray</td>
<td>25426</td>
<td>58295</td>
<td>134598</td>
<td>244011</td>
<td>148411</td>
<td>72848</td>
<td>97771</td>
<td>1935</td>
<td>16</td>
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<tr>
<td>Skin</td>
<td>148112</td>
<td>141589</td>
<td>65504</td>
<td>57098</td>
<td>2305</td>
<td>5009</td>
<td>6334</td>
<td>10</td>
<td>0</td>
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<tr>
<td>Green</td>
<td>114258</td>
<td>262118</td>
<td>556562</td>
<td>570697</td>
<td>467943</td>
<td>184644</td>
<td>57915</td>
<td>739</td>
<td>3</td>
</tr>
<tr>
<td>Sky</td>
<td></td>
<td>129770</td>
<td>129770</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>287796</td>
<td>462002</td>
<td>886434</td>
<td><strong>1001576</strong></td>
<td>618659</td>
<td>262501</td>
<td>141286</td>
<td>2684</td>
<td>19</td>
</tr>
</tbody>
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Experiments

◆ Performance evaluation in perspective
  – Requirement for evaluation
    • Compilation of a test image and illuminant database

◆ Proof of concept experiment
  – Using more than three hundred images
    • Including outdoor scene with people on sunny and overcast days
    • Sunrise to sunset, and indoor scene

◆ Performance evaluation through comparison
  – Comparison with gray world algorithm
Fig. 7. Left: gray world algorithm. Right: memory color algorithm.
Table 2. Calculated errors (all numbers were multiplied by 100).

<table>
<thead>
<tr>
<th>error</th>
<th>max</th>
<th>min</th>
<th>RMS</th>
<th>median</th>
<th>mean</th>
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<tbody>
<tr>
<td>Memory Color</td>
<td>7.4239</td>
<td>0.2433</td>
<td>0.3967</td>
<td>2.0387</td>
<td>2.6908</td>
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<tr>
<td>Gray World</td>
<td>8.0401</td>
<td>0.6226</td>
<td>0.4656</td>
<td>2.9685</td>
<td>3.2805</td>
</tr>
</tbody>
</table>

\[ \varepsilon = \sqrt{(r_{\text{real}} - r_{\text{esti}})^2 + (g_{\text{real}} - g_{\text{esti}})^2} \]  

(4)

\[ \varepsilon_{RMS} = \frac{1}{N} \sqrt{\sum_{i=1}^{N} \varepsilon^2} \]  

(5)
Conclusion

◆ Proposed method
  – Pixel based illuminant estimation
    • Clustering of pixels
      – Neutral color and three dominant memory colors: skin tone, sky blue, and foliage green
  – Comparison with gray world theory
    • More effective estimation of illuminant