Spectral Differencing using Several Images

- **Spectral differencing**
  - Definition of algorithm
    - Detection of highlights in color image
      - Acquiring multiple colour image from different viewing direction
    - Computing algorithm of spectral differentiation
      - Using minimum spectral distances (MSD)
      - Presupposing color of lighting and color of objects differ in scene
– Calculation of MSD image

  • Minimum value of all spectral distance between \( C_\alpha \) and \( C_\beta \)

\[
MSD \quad C_\alpha \leftarrow C_\beta
\]

where \( C_\alpha \) and \( C_\beta \) are two color images taken from different views

  • Spectral distance and color distance between color pixel
    – Defining Euclidian distance in three dimensional color space

  • Threshold of MSD value
    – Above presence of mirroring reflection
    – Depends only on sensor noise
    – Independent of viewers direction
– two difference views of object with specular surface component

Fig. 8.7. Spectral differencing: (a) Images from different views; (b) associated color clusters in the RGB space
Photometric Multi-Image Technique

- Method for highlight elimination
  - Photometric multi-image technique
    - Photometric stereo analysis technique
      - Using three-color images
    - Finding identical viewer direction
      - Using three different lighting direction
– Procedure

• Based on one object point in scene
• Three measured color values in three color images
• Representing each pixel position by three color vector
  – $c_1$ from $C_1$, $c_2$ from $C_2$, $c_3$ from $C_3$
• According to dichromatic reflection model
  – Three vectors lies same dichromatic plane
  – Producing same light source color
• Principal position of three color vector in dichromatic plane for any object point
Generating matte image

- Presuppose vector of light source color $C_s$ is known
- Position of three color vector in dichromatic plane

Fig. 8.8. Principle of a photometric multi-image technique. (a) Three color images taken with differing lighting directions; (b) Principle position of three color vectors in the dichromatic plane for any object point (c) Position of three color vectors in the dichromatic plane, if the color vector in image $C_3$ does not contain a highlight.
<table>
<thead>
<tr>
<th>Spectral Differencing</th>
<th>Photometric Multi-Image Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highlights can be only detected, not eliminated.</td>
<td>Highlights can be detected and eliminated.</td>
</tr>
<tr>
<td>The color of the light source does not need to be known.</td>
<td>The color of the light source must be known and identical in all images.</td>
</tr>
<tr>
<td>Object colors and light source color cannot be identical (i.e., no white objects may be present in white light).</td>
<td>Object colors and light source color cannot be identical (i.e., no white objects may be present in white light).</td>
</tr>
<tr>
<td>The technique can be applied to moving or nonrigid objects if it is guaranteed that all three color images are generated at the same time.</td>
<td>The color images must always be produced successively. Thus, the objects must be rigid and sturdy.</td>
</tr>
<tr>
<td>Pixels that are not visible in all images can be falsely classified as highlight pixels. Contrarily, highlight pixels that lie within the overlapping region between two planar color clusters are usually not recognized as highlight pixels.</td>
<td>No highlight elimination can be implemented in the image domains that are not illuminated in all three images.</td>
</tr>
<tr>
<td>The procedure can be accomplished locally for an individual pixel. However, the color distances of the single pixel to all pixels in the other image must be determined.</td>
<td>The procedure can be implemented locally for a single pixel. Only the three color values from the three color images are needed.</td>
</tr>
</tbody>
</table>
Polarization Technique

Detecting highlight

- Implementation of polarization filter
  - Idea of polarization technique
    - Specular reflectance component is polarized
  - Several method for highlight identification
    - Combining spectral differencing with polarization technique
      - Acquiring image
        » Using black-and-white camera from two different observers locations
        » Using each of three differing polarization angles
      - Advantage of this technique
• Using color and polarization
  – Measuring color vector
    \[ L = L_b + L_s \]
    where \( L_b \) indicates diffuse and \( L_s \) specular component
    » Diffuse reflection is unpolarized
    » Specular component is polarized
  – Rotation of polarization filter
    » Measuring value of specular component
    » Describing specular component
      » Sum of constant vector \( L_{SC} \) and consine function term with
        amplitude \( L_{SV} \)
        \[ L_i = L_b + L_{SC} + L_{SV} \cos 2\theta_i - \alpha \]
    where rotation angle \( \theta_i \) of polarization filter, color vector
    \( \alpha \) describe phase angle that is determine by projecting
    surface normals of represented object pixels into plane of
    polarization filter
– Calculating Maximum and minimum polarization

\[ L_{\text{max}} = L_c + L_{SV} \quad \text{and} \quad L_{\text{min}} = L_c - L_{SV} \]

– Calculating component of vectors

\[
\begin{pmatrix}
L_{\text{max}} \\
L_{\text{max}} \\
L_{\text{max}}
\end{pmatrix}
= \begin{pmatrix}
R \\
G \\
B
\end{pmatrix}
\quad \text{and} \quad
\begin{pmatrix}
L_{\text{min}} \\
L_{\text{min}} \\
L_{\text{min}}
\end{pmatrix}
= \begin{pmatrix}
R \\
G \\
B
\end{pmatrix}
\]

– Expressing degree of polarization

\[
\omega = \begin{pmatrix}
\omega R \\
\omega G \\
\omega B
\end{pmatrix}
= \begin{pmatrix}
L_{\text{max},R} - L_{\text{min},R} \\
L_{\text{max},G} - L_{\text{min},G} \\
L_{\text{max},B} - L_{\text{min},B}
\end{pmatrix}
\quad \text{and} \quad
\begin{pmatrix}
L_{\text{max},R} - L_{\text{min},R} \\
L_{\text{max},G} - L_{\text{min},G} \\
L_{\text{max},B} - L_{\text{min},B}
\end{pmatrix}
\]
• Condition of pixel $P$ to purely diffuse
  – Color of specular similar to component diffuse
    » Component of vector $\omega$ must be smaller than threshold value
    » Angle between vector $L_{\min}$ and $L_{\max}$ must be greater than second threshold value
  – Condition of pixel $P$ to polarized
    » Continuation with diffuse component
    » $L_b$ cannot locally computed from estimation for $L_c = L_b + L_{sc}(L_{sv})$
  – Position of $P$ on $L$

$$P = L_{\min} - d \frac{L_{SV}}{\|L_{SV}\|}$$

where $d$ is distance from $P$ to $L_{\min}$
• Computing diffuse component

Fig. 8.9. Use of point from the neighborhood of $P$ for determining diffuse component