Digital Color Image Processing

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Andreas Koschan, and Mongi Abidi

Presented by Ran Shu

School of Electrical Engineering and Computer Science
Kyungpook National Univ.
Edge-based correspondence analysis

- Edge-based correspondence analysis in color stereo images
  - Existing few techniques
    - Edge containing no color information
    - Selected for reducing computation time
    - Correlation between color channels
      - 90% edges identical
        » Gray-level image
        » Color image
  - Reducing ambiguities during correspondence analysis
    - Using color information in edge-matching process
      - Reducing false matches of edges
        » Only monochromatic-based techniques
– Selection of matching candidates for all zero crossings in left image
  • Following three criteria in fundamental matching algorithm
    – Zero crossing in right image lying within search area
    – Same contrast condition
    – Approximately same orientation
– Reducing number of false positive matches
  • Using color information
    – Determining zero crossings individually
      » For each component of color vectors
        » Gray-level algorithm separately for each component
    – Using color information for characterizing zero crossings
      » In gray-level image
Description of color information varies at zero crossing

- In LoG-filtered gray-level image
  - Using monochrome displacing frame difference image

\[ D_{rg}(x, y) = r(x, y) - g(x, y) = \frac{R(x, y) - G(x, y)}{R(x, y) + G(x, y) + B(x, y)} \]

- Sign of direction variation along horizontal line
  - Defining sign of gradient of smoothed displace frame difference image

\[ \frac{\delta}{\delta x} \left( \text{GAUSS} \ast D_{rg} \right) = \left( \frac{\delta}{\delta x} \text{GAUSS} \right) \ast D_{rg} \]

where \( \text{GAUSS}(x, y) \) indicates two dimension Gaussian function,
* indicates convolution operation
• Orientation of gradient
  - Given for smoothed difference image

\[
\tan^{-1}\left( \frac{\frac{\delta}{\delta y} (GAUSS * D_{rg})}{\frac{\delta}{\delta x} (GAUSS * D_{rg})} \right)
\]

• Expanding matching algorithm
  • Signs of gradients equal for each standardized difference image
    - In both candidates
Disparity gradient limit for color images

- Instead of viewing difference images
  - Chromatic gradient constraint
    » Determining two gray-level images
    » Determining two color channels

\[
\begin{align*}
\left| E_{L_x} \left( x - \frac{\delta - b}{2}, y \right) - E_{R_x} \left( x + \frac{\delta + b}{2}, y \right) \right| & \leq \frac{1}{2} \left| E_{L_x} \left( x - \frac{\delta - b}{2}, y \right) + E_{R_x} \left( x + \frac{\delta + b}{2}, y \right) \right| + 2\sqrt{2}\delta_x \\
\left| E_{L_y} \left( x - \frac{\delta - b}{2}, y \right) - E_{R_y} \left( x + \frac{\delta + b}{2}, y \right) \right| & \leq \frac{1}{2} \left| E_{L_x} \left( x - \frac{\delta - b}{2}, y \right) + E_{R_x} \left( x + \frac{\delta + b}{2}, y \right) \right| + 2\sqrt{2}\delta_x
\end{align*}
\]

where \( E_{L_x}, E_{R_x} \) indicate partial derivatives,
\( \delta \) value that assumes column difference,
\( b \) base line,
\( \sigma_x, \sigma_y \) standard derivatives for an additive noise in gray-level image
Percentages of changes in result

**Table 9.2.** Percentage changes of results using additional criterion 4 instead of gray level algorithm gathered from four color stereo images according to [JorBov91]

<table>
<thead>
<tr>
<th>Measured Quantity</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of matching candidates</td>
<td>-28.5</td>
</tr>
<tr>
<td>Number of definite matches</td>
<td>+191.3</td>
</tr>
<tr>
<td>Percentage number of correct matches</td>
<td>+246.3</td>
</tr>
</tbody>
</table>
General ideas

- Reducing ambiguities in edge-based correspondence analysis
  - Evaluating color information
  - Using a good color edge finder
    - Edges from physical causes
      - Orientation edges
      - Reflection edges
      - Illumination edges
        » Mismatching with dynamic stereo analysis
    - Highlight edges
      » Depending on observer position
    - Occlusion edges
      » Depending on observer position
Automatic classification of image value edges in color images
- Under certain preconditions
- Great computational cost

Fig. 9.16. Example of observer location dependent cover and highlight edges in stereo images
Dynamic and photometeric stereo analyses in color images

- Optical flow
  - Evaluating projected motion vector
    - Supporting calculation of gradient vectors
    - Supporting depth values
      - Representing as field of local displacement vectors
        » Calculated by optical flow
Solution strategy

- Optical flow can be analyzed for any image sequences
  - Including nonrigid objects
    - Aiding motion estimation
- Optical flow cannot be identified generally with field of local displacement
  - Sphere without texture
- Aperture problem
  - No indication or inadequate information about motion vectors
    - Gained from locally restricted image region
- Camera instability
  - Changing illumination or by different surface appearance
    - For different viewing directions
Illustration of the aperture problem in motion analysis

Fig. 10.1. In sole (local) observation of the circle area in both images of an image sequence, the movement of the object (movement of the rectangle toward the upper-right corner) cannot be unambiguously detected.
- Optimal flow of image $E_i$ to image $E_{i+1}$
  - Characterizing changes of image irradiances
    \[ u_i(x, y) = (u_i(x, y), v_i(x, y))^T \]
  - Assuming equation
    \[ E(x + u_i(x, y), y + v_i(x, y), t_{i+1}) = E(x, y, t_i) \]
  - or
    \[ E(x + u_i(x, y), y + v_i(x, y), t_i + \delta t_{const}) = E(x, y, t_i) \]