Consistent Optical Flow for Stereo Video

ICIP 2010

Anita Sellent, Christian Linz, Marcus Magnor

TU Braunschweig, Germany
Monocular Video Editing

- Propagating keyframe information based on Optical Flow
Monocular Video Editing

- Propagating keyframe information based on **Optical Flow**

  ![Image of optical flow](image)

  Inaccurate flow estimation requires manual interaction

  [Eisemann et al. 2009]
Stereoscopic Video Editing

- Correspondence between temporally and spatially neighboring images

- Uncalibrated and non-synchronized cameras
Consistent Optical Flow

- Optical flow estimation between image pairs
  ⇒ Small errors accumulate quickly
Key Idea

- Exploit redundant data in stereo video
- Calculate flow on **three** images simultaneously
Outline

- The basic two image flow
- The symmetry constraint
- The loop constraint
- Iterative flow estimation
- Propagation over a sequence
- Results
Basic Two Image Flow

- Brightness constancy assumption

\[ I_1(x) - I_2(x + w_{1,2}) \approx 0 \]

- Smoothness term: total variation, Huber norm

\[ |\nabla w_{1,2}|, \quad |D^{0.5}\nabla w_{1,2}| \]

- Global energy

\[
\min_{w_{1,2}} \int_{\Omega} \lambda |I_1 - I_2(x + w_{1,2})| + |\nabla w_{1,2}| \, dx
\]
Splitting the Energy Function

- Auxiliary variable $z_{1,2}$

\[
\min_{w_{1,2}, z_{1,2}} \int_{\Omega} \lambda \left| I_1 - I_2(x + w_{1,2}) \right| + \frac{2}{\theta} \left\| w_{1,2} - z_{1,2} \right\| + \left\| \nabla z_{1,2} \right\| dx
\]

- Pointwise problem

\[
\min_{w_{1,2}} \lambda \left| I_1 - I_2(x + w_{1,2}) \right| + \frac{1}{\theta} \left\| w_{1,2} - z_{1,2} \right\|
\]

- Image denoising problem

\[
\min_{w_{1,2}, z_{1,2}} \int_{\Omega} \frac{1}{\theta} \left\| w_{1,2} - z_{1,2} \right\| + \left\| \nabla z_{1,2} \right\| dx
\]
The Symmetry Constraint

[Alvarez et al. 2007]

Symmetry error:

\[ \rho_s = w_{1,2}(x) + w_{2,1}(x + w_{1,2}) \approx 0 \]

\( I_2 \) : \( w_{1,2} \) : flow from \( I_1 \) to \( I_2 \)

\( I_1 \) : \( w_{2,1} \) : flow from \( I_2 \) to \( I_1 \)
The Loop Constraint

Loop error:

\[ \rho_L = w_{1,2}(x) + w_{2,3}(x + w_{1,2}) + w_{3,1}(x + w_{1,2} + w_{2,3}) \approx 0 \]
Update scheme

- Determine incremental update $dw_{i,j}$ from brightness constancy
- Evaluate satisfaction of symmetry and loop constraint for this estimate
  \[ p = e^{-a \rho_s^2} e^{-b \rho_l^2} \]
- Update current flow field
  \[ w_{i,j}^{k+1} = w_{i,j}^k + p \, dw_{i,j} \]
- Use current flow estimation to determine TV-optimized version $z_{i,j}$
- Proceed with next flow field $w_{j,h}$
### Consistent Update

- Update flow field only when symmetry and loop constraint are satisfied
- Rely on smooth fill-in otherwise
- Brightness constancy for occluded points is suppressed
Propagation in a Sequence

- Use known flow fields to constrain the new flow fields
Propagation II

Consistent Optical Flow for Stereo Video

Anita Sellent
Propagation II

... ...

Consistent Optical Flow for Stereo Video

Anita Sellent
Propagation II

... ...
Consistent Optical Flow for Stereo Video
Anita Sellent
Propagation II

... ...
Propagation II
Results

- Test sequences with ground-truth

[Vaudrey et al. 2008]

[Scharstein et al. 2007]
## Results AEE

<table>
<thead>
<tr>
<th>AEE</th>
<th>Wave</th>
<th>.enpeda</th>
<th>Art</th>
<th>Books</th>
<th>Dolls</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV-L2</td>
<td>1.03</td>
<td>0.71</td>
<td>10.62</td>
<td>14.60</td>
<td>5.81</td>
</tr>
<tr>
<td>Symmetry</td>
<td>1.01</td>
<td>0.61</td>
<td>10.02</td>
<td>10.73</td>
<td>2.93</td>
</tr>
<tr>
<td>Loop</td>
<td>0.97</td>
<td>0.59</td>
<td>9.34</td>
<td>6.43</td>
<td>2.85</td>
</tr>
</tbody>
</table>

Consistent Optical Flow for Stereo Video  
Anita Sellent
Results Consistency

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Wave</th>
<th>enpeda</th>
<th>Art</th>
<th>Books</th>
<th>Dolls</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV-L2</td>
<td>1.24</td>
<td>4.01</td>
<td>3.00</td>
<td>17.45</td>
<td>11.37</td>
</tr>
<tr>
<td>Symmetry</td>
<td>0.16</td>
<td>1.29</td>
<td>2.69</td>
<td>6.30</td>
<td>7.60</td>
</tr>
<tr>
<td>Loop</td>
<td>0.13</td>
<td>0.87</td>
<td>1.71</td>
<td>4.27</td>
<td>2.84</td>
</tr>
</tbody>
</table>

Consistent Optical Flow for Stereo Video
Anita Sellent
Conclusion

- Estimate flow fields between three images simultaneously
- Prevent error accumulation
- Disable brightness constancy for occluded points

⇒ Consistent and more accurate flow fields
Thank You for Your Attention!

https://graphics.tu-bs.de