Color Segmentation Based Depth Filtering

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Overview

- Depth Filtering
- Our Approach
- Results
  - Qualitative
  - Quantitative analysis method
- Conclusion
Depth Filtering

• Depth generation methods:
  – Active
    • Laser Scanner
    • ToF
    • Structured Light
  – Passive
    • Depth from stereo
    • Depth from motion
    • Depth from X

• There are no perfect depth maps
Example depth map

- Kinect (structured light camera)
OUR APPROACH
Our Approach

- Focuses on edge restoration
- Takes edge information of associated color stream
- Workflow:
  1. Occlusion Filling
  2. Segmentation of color stream
  3. Computation of representative depth map
  4. Edge restoration
  5. Post processing
Occlusion Filling

- Normalized convolution

\[ D^{nc}(x) = \frac{\sum_{x' \in N_x} D(x)g(x, x')} {\sum_{x' \in N_x} g(x, x')} \]
Color Segmentation

• Edge information is taken from an oversegmentation (superpixel segmentation)

• We take Watershed segmentation because
  – Fast
  – Compact segments
  – Segments of approx. the same size (except thin “edge segments”)

• Color Segmentation:
  – Preprocessing of color stream (bilateral filter because of noise)
  – Apply Watershed
  – Cluster Splitting
Watershed Segmentation

• Idea of Watershed:
  – Interpret Grayscale image as relief
  – Place water sources on it
  – Flood relief and draw borders where lakes meet
  – Apply Bilateral Filter prior to reduce noise
Watershed Color Segmentation
Projected Color Segmentation in Depth
Representative Depth Map

- Compute a representative depth value for each segment

\[ D^r(x, y) = \{ d_k : (x, y) \in S_k, \quad d_k = \text{median}_{(x', y') \in S_k} d(x', y') \} \]
Edge Restoration

- Use representative depth map to enhance edges:

\[
D^f(x, y) = \begin{cases} 
D^r(x, y) & \text{if } |D(x, y) - D^r(x, y)| > \theta \\
D(x, y) & \text{otherwise}
\end{cases}
\]

- Outliers are corrected by depth values of the representative depth map

- Postprocessing: Bilateral Filter

\[
I(p) = \frac{\sum_{q \in N} K_s(||p - q||)K_c(||p - q||)I(q)}{\sum_{q \in N} K_s(||p - q||)K_c(||p - q||)}
\]
RESULTS
Original Depth Map
Normalized Convolution [9]
Berdnikov et al. [6]
Wasza et al. [7]
Our method
Qualitative Results

Input depth map

Our method
Quantitative Results - Method

• Test sequence: Clear foreground and background

• Other geometry is possible
Quantitative Results - Method

- Color frames define a clustering into foreground and background
- Depth frames define a clustering into foreground and background
- Perfect depth map -> Same clusterings
- Measure cluster similarity using Rand Index
  - Gives values between 0 and 1
Quantitative Results

![Graph showing quantitative results with different methods and frames.](image-url)
Quantitative Results

• Test sequence 2:
## Quantitative Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Sequence 1</th>
<th>Sequence 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our method</td>
<td>0.9865</td>
<td>0.9778</td>
</tr>
<tr>
<td>Berdnikov [6]</td>
<td>0.9118</td>
<td>0.9129</td>
</tr>
<tr>
<td>Knutsson [9]</td>
<td>0.8952</td>
<td>0.9120</td>
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<tr>
<td>Wasza [7]</td>
<td>0.8899</td>
<td>0.9121</td>
</tr>
</tbody>
</table>

Mean Rand Index Values
CONCLUSION
Conclusion

• We presented a new method for depth map enhancement
• Special focus on edge restoration
• We introduced a new method to quantify our results
• Our method shows promising results and outperforms others in terms of Rand Index values
• Future Work:
  – Add a temporal component
  – Make color segmentation temporal stable
References


Thank you.

Questions?