Color Segmentation Based Depth Filtering

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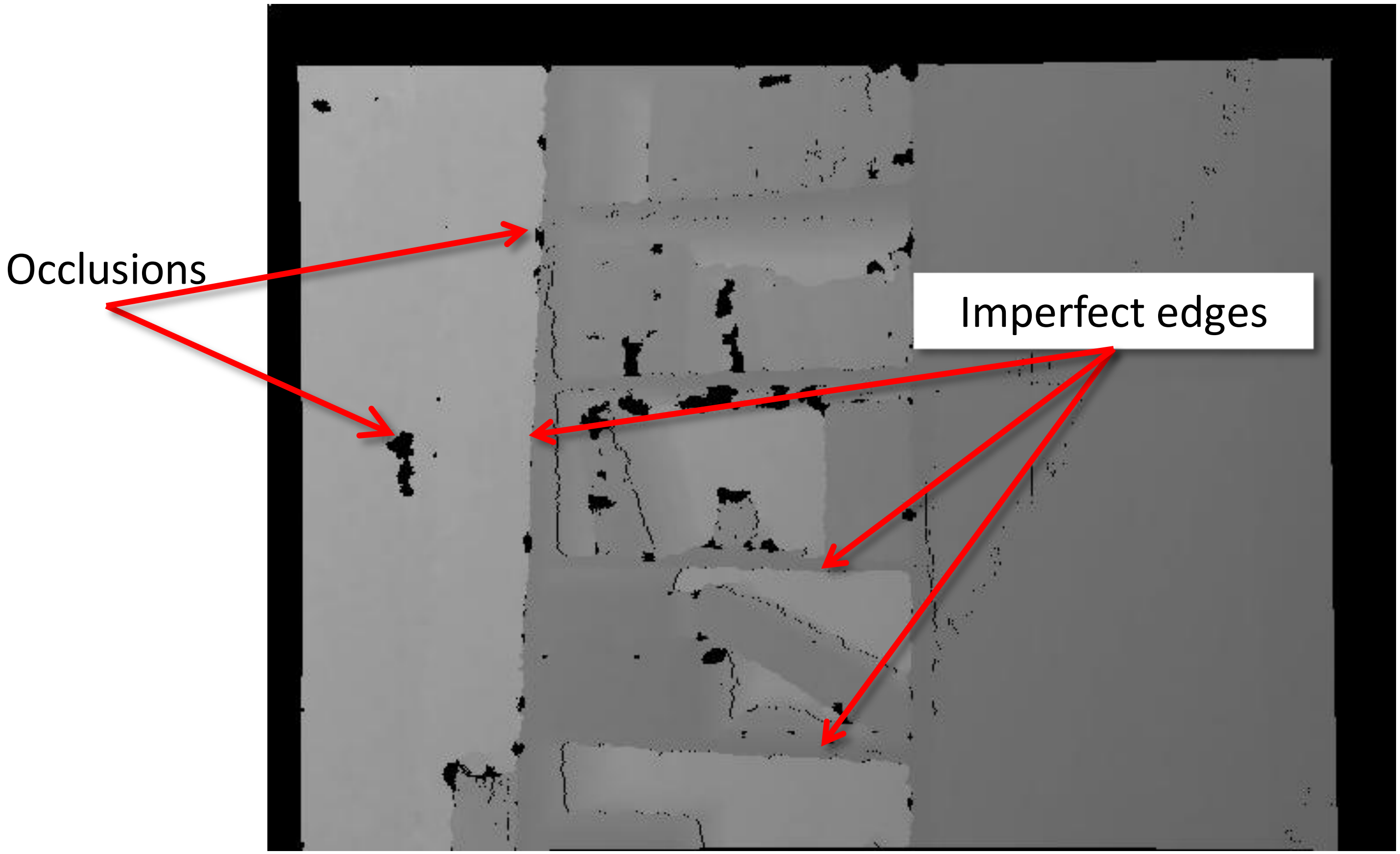
Overview

- 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

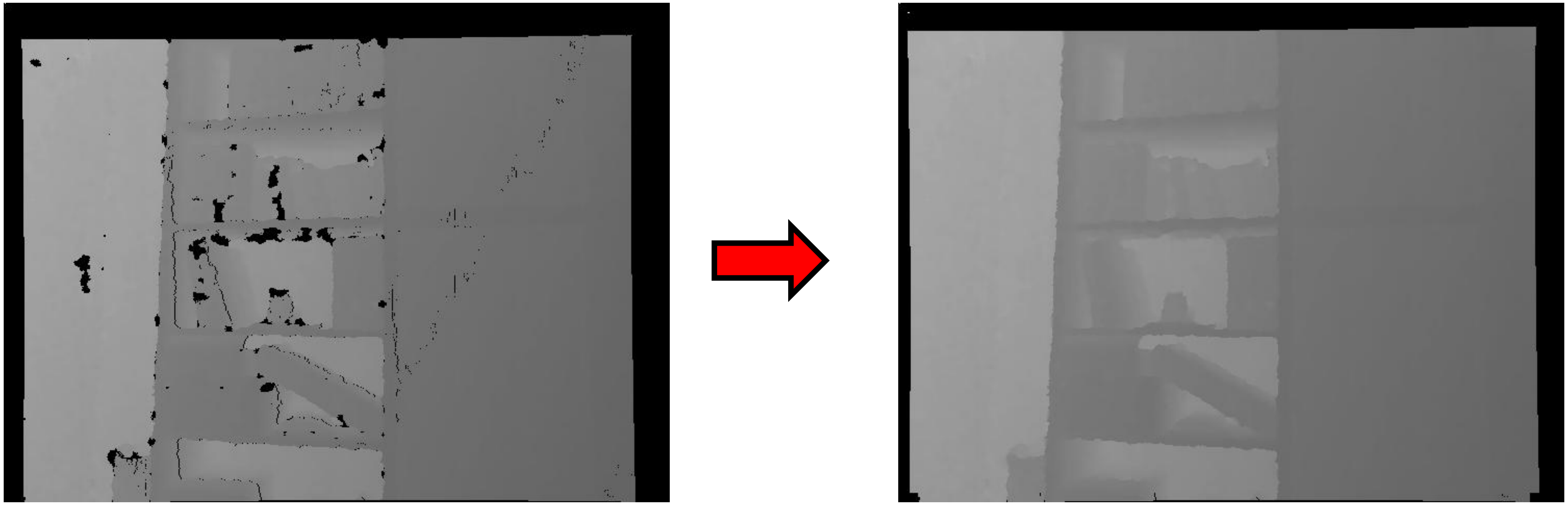
Our Approach

- 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

$$D^{nc}(x) = \frac{\sum_{x' \in N_x^*} D(x) g(x, x')}{\sum_{x' \in N_x^*} g(x, x')}$$

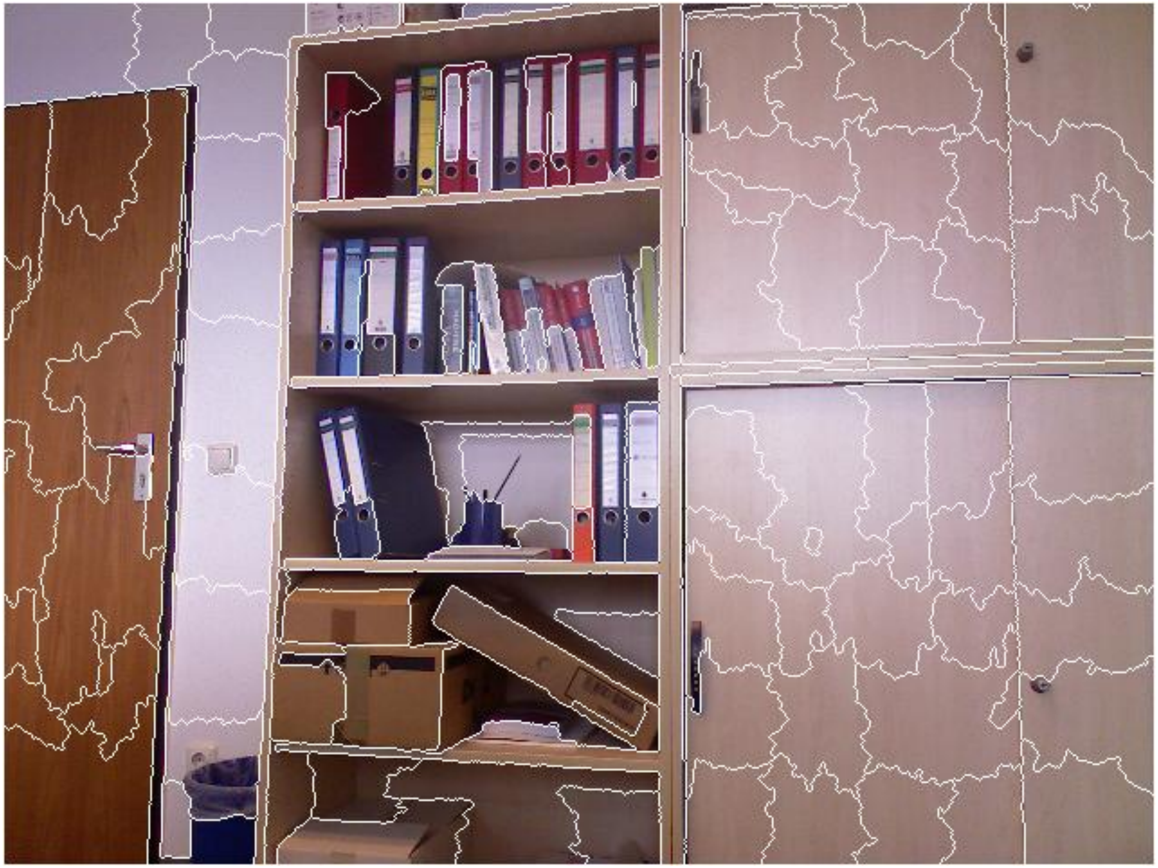


Color Segmentation

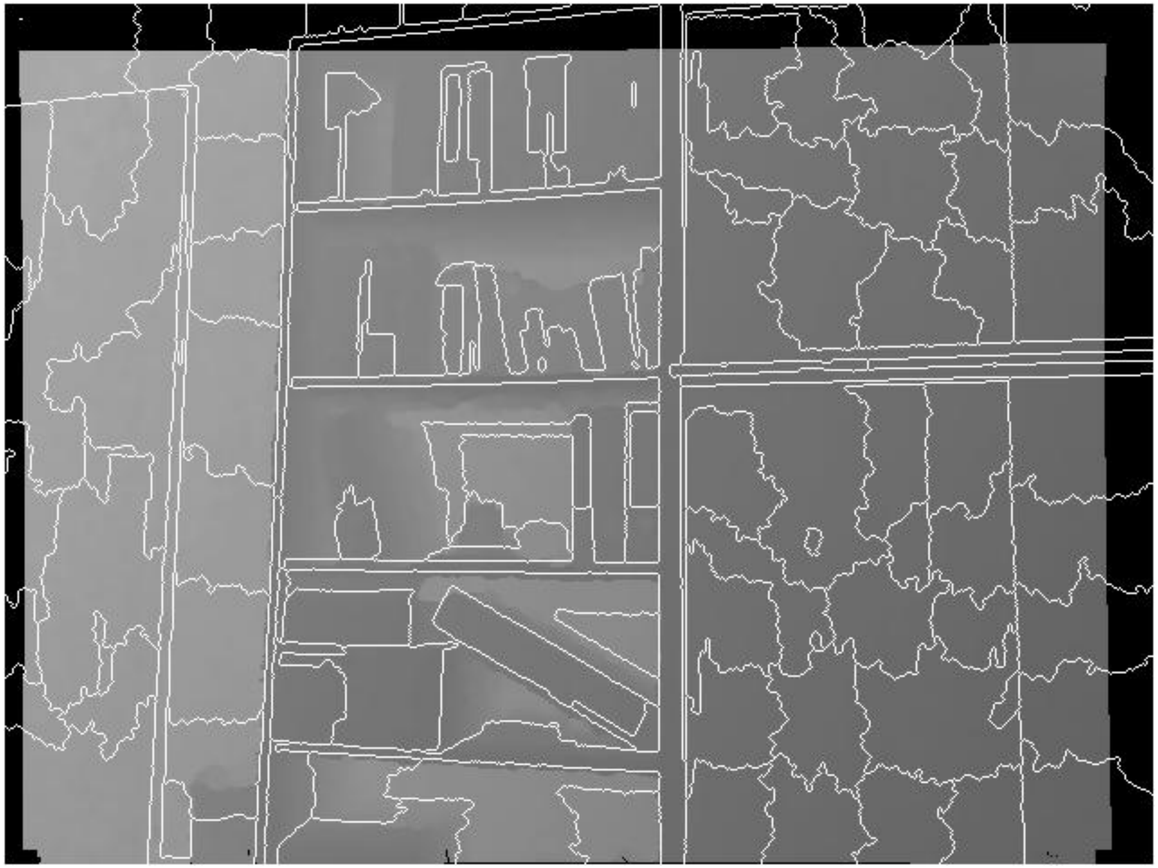
- Edge information is taken from an oversegmentation (superpixel segmentation)
- We take Watershed segmentation because
  - Fast
  - Compact segments
  - Segments of approx. the same size (except thin "edge segments")
- Color Segmentation:
  - Preprocessing of color stream (bilateral filter because of 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

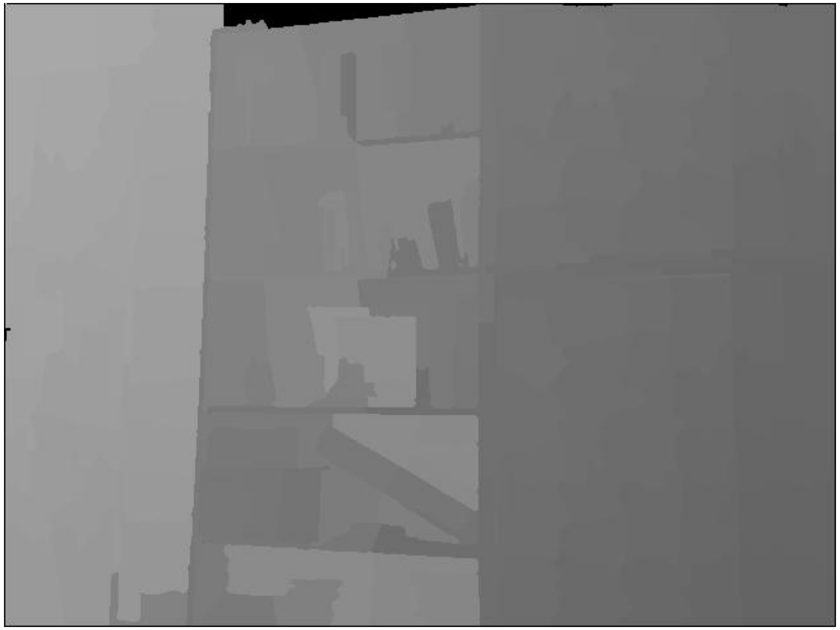


Projected Color Segmentation in Depth

Representative Depth Map

- Compute a representative depth value for each segment

$$D^r(x,y) = \{d_k : (x,y) \in S_k,\ d_k = \operatorname*{median}_{(x',y') \in S_k} d(x',y')\}$$



Edge Restoration

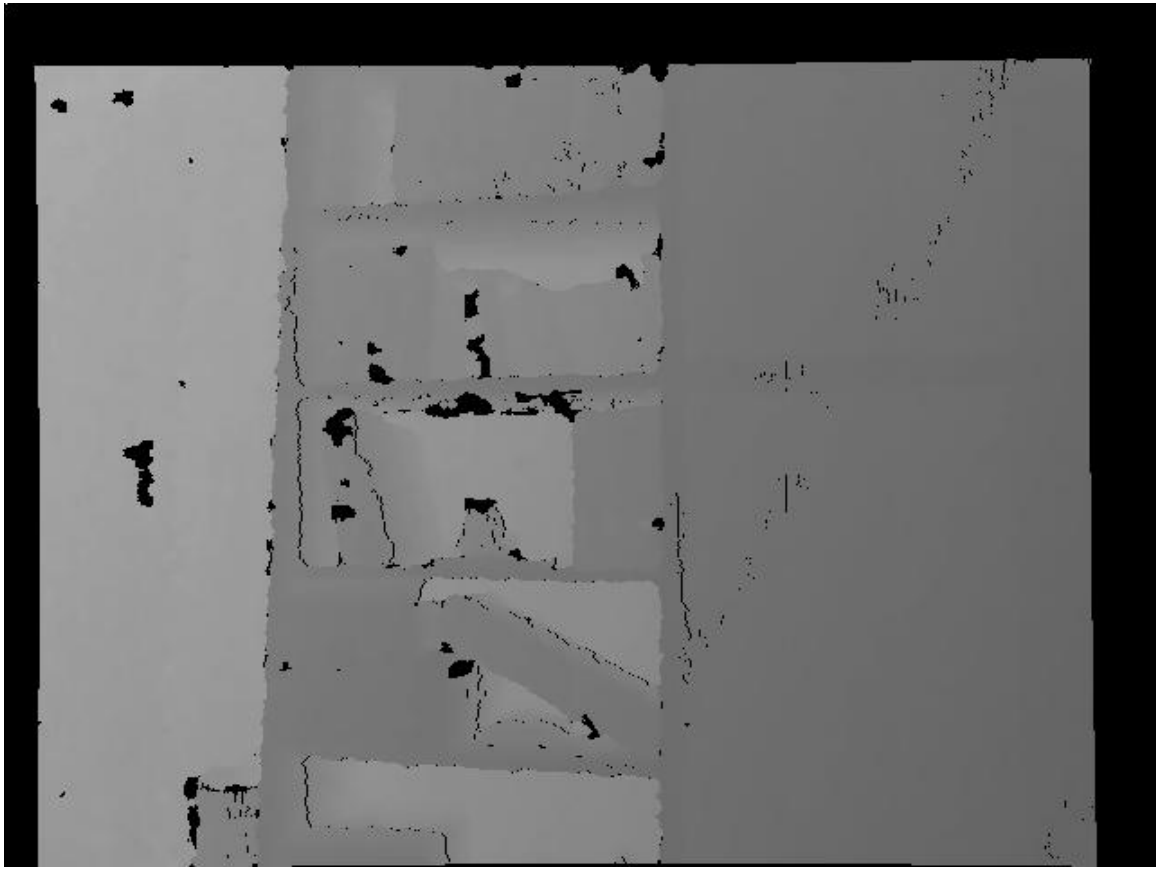
- Use representative depth map to enhance edges:

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

- 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

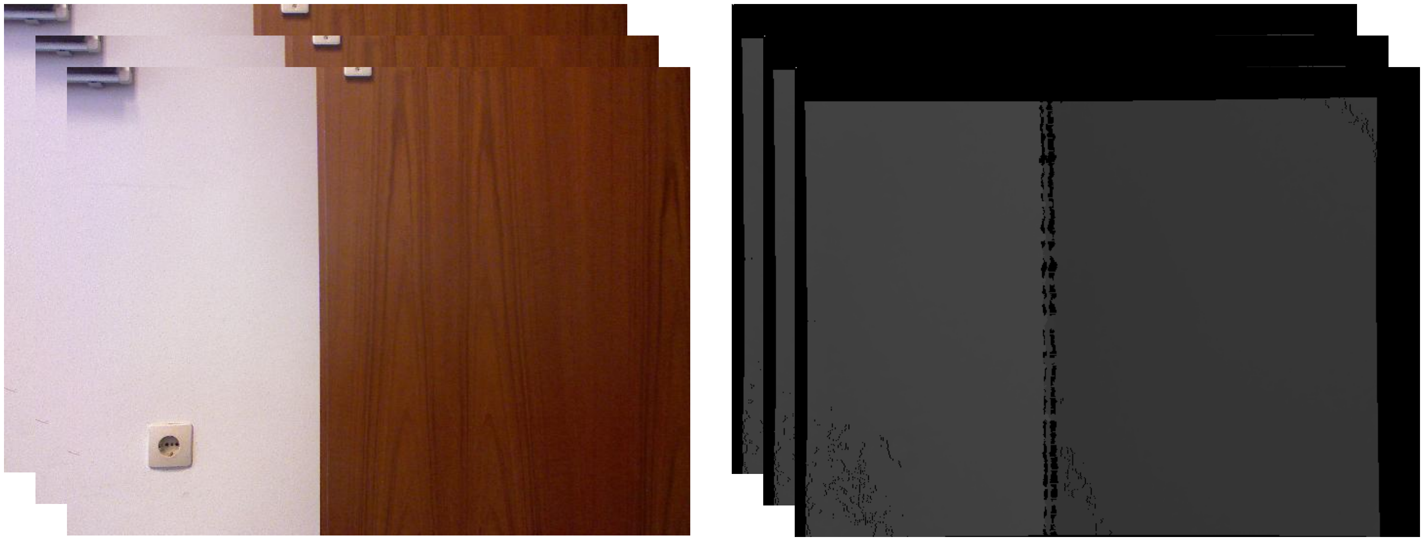
Qualitative Results

Input depth map

Our method

Quantitative Results - Method

- Test sequence: Clear foreground and background

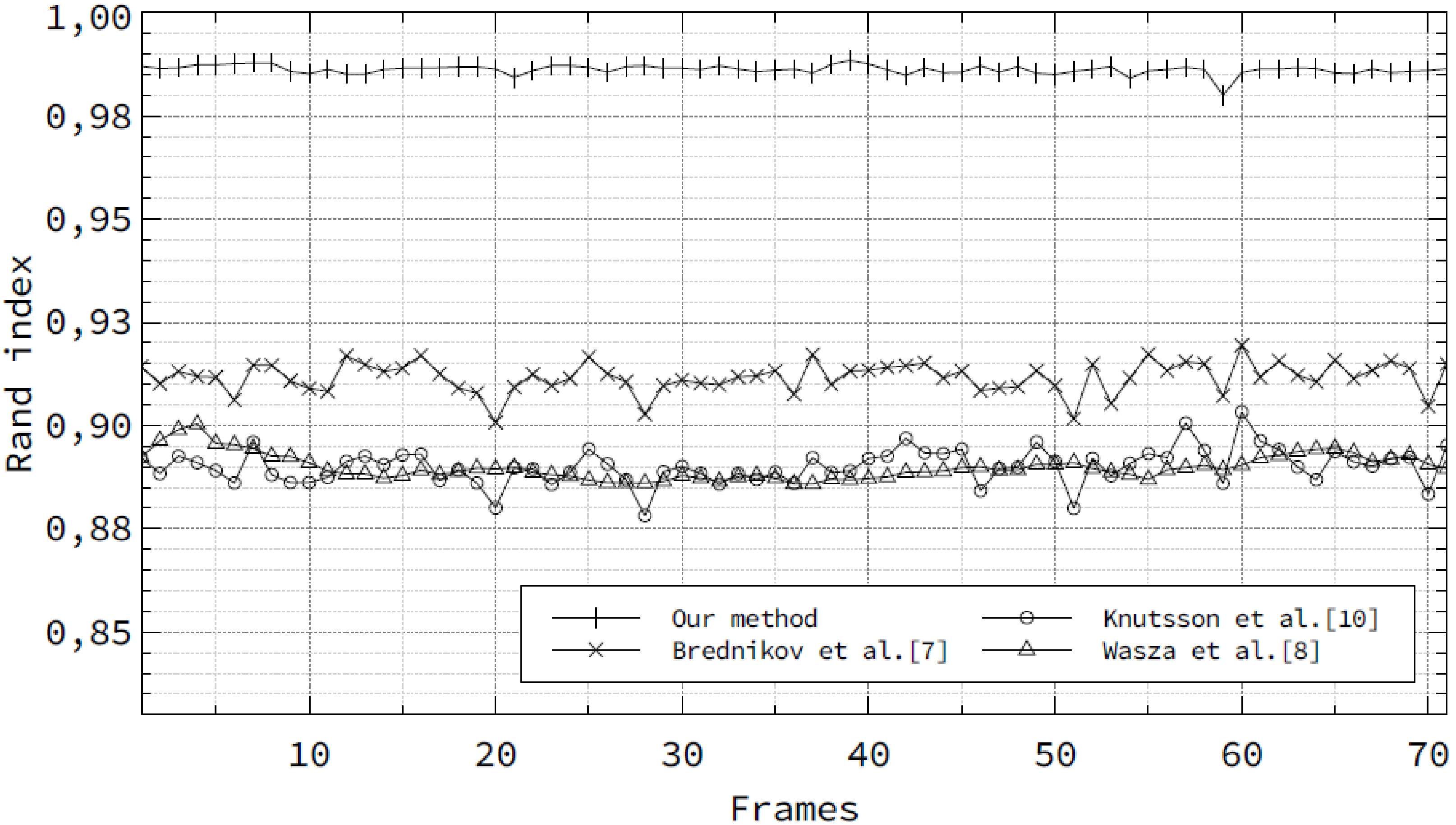


- Other geometry is possible

Quantitative Results - Method

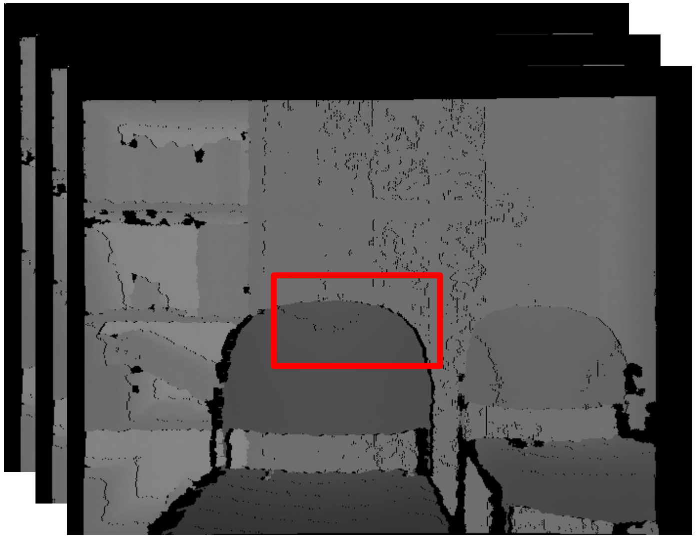
- Color frames define a clustering into foreground and background
- Depth frames define a clustering into foreground and background
- Perfect depth map -> Same clusterings
- Measure cluster similarity using Rand Index
  - Gives values between 0 and 1

Quantitative Results



Quantitative Results

- Test sequence 2:



Quantitative Results

	Sequence 1	Sequence 2
Our method	0.9865	0.9778
Berdnikov [6]	0.9118	0.9129
Knutsson [9]	0.8952	0.9120
Wasza [7]	0.8899	0.9121

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

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- [12] Beucher, S., Lantuejoul, C.: Use of Watersheds in Contour Detection. In: International Workshop on Image Processing: Real-time Edge and Motion Detection/Estimation, Rennes, France. (1979)
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Thank you.

Questions?