DENOISING OF VOLUMETRIC DEPTH CONFIDENCE FOR VIEW RENDERING

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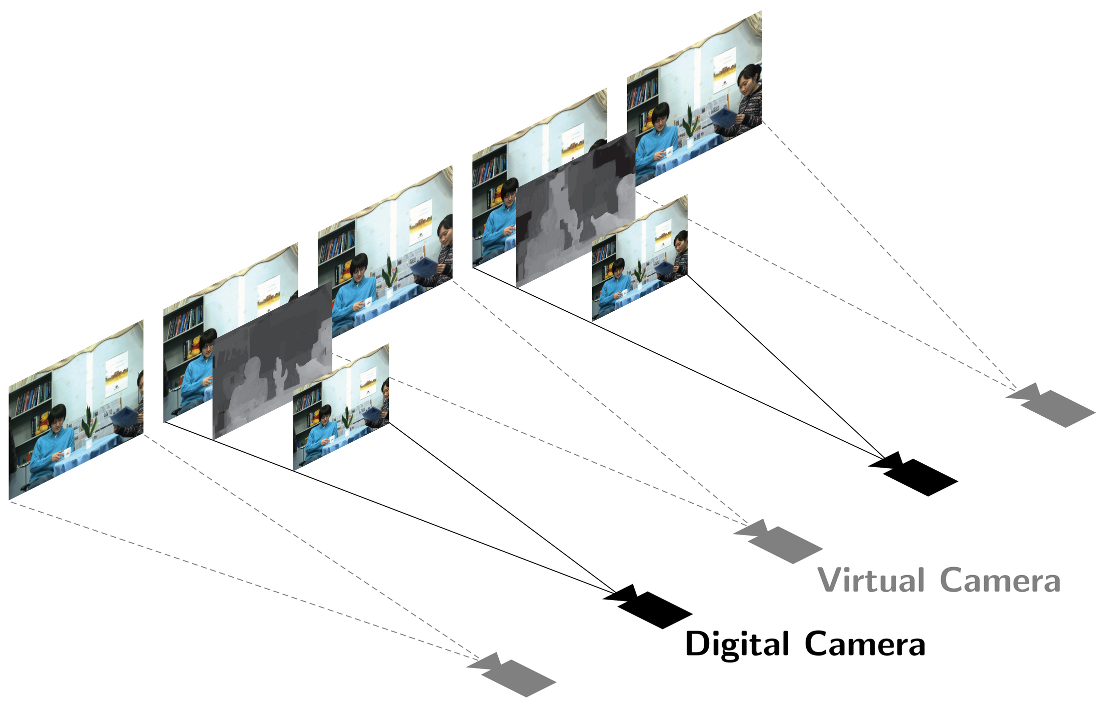
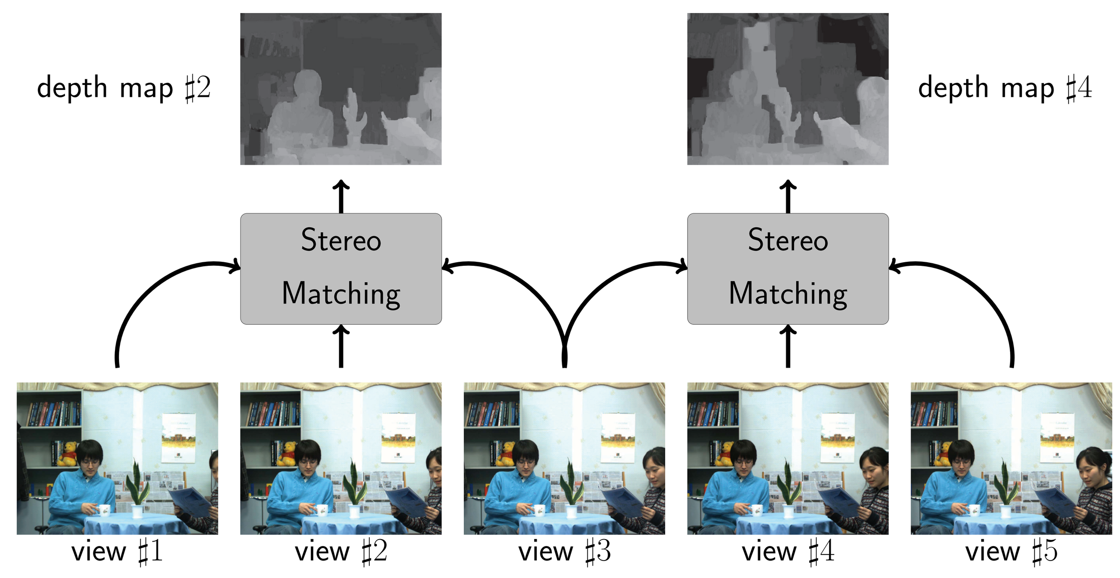
1 MOTIVATION

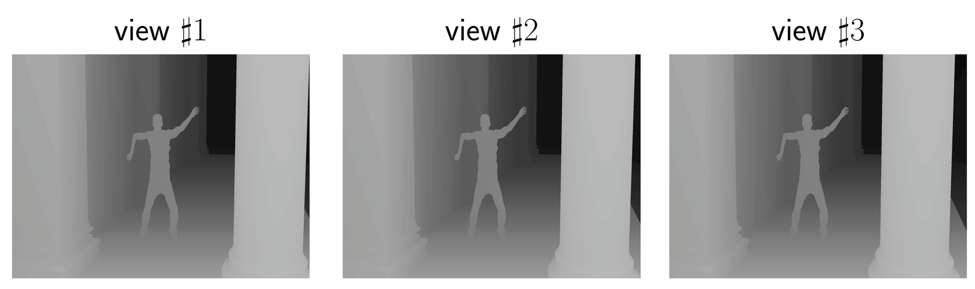
Free-Viewpoint Television



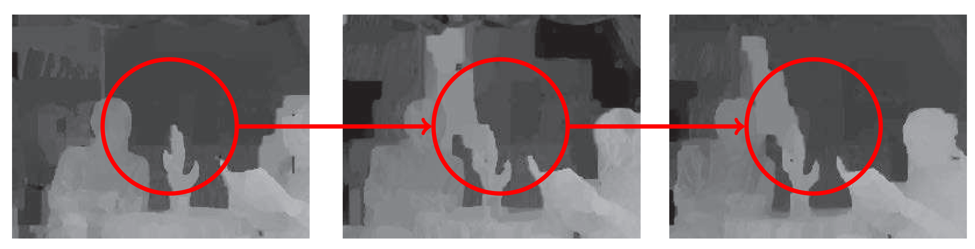
Depth Map Estimation



Inconsistency of Multiview Depth Imagery



(a) Dancer.

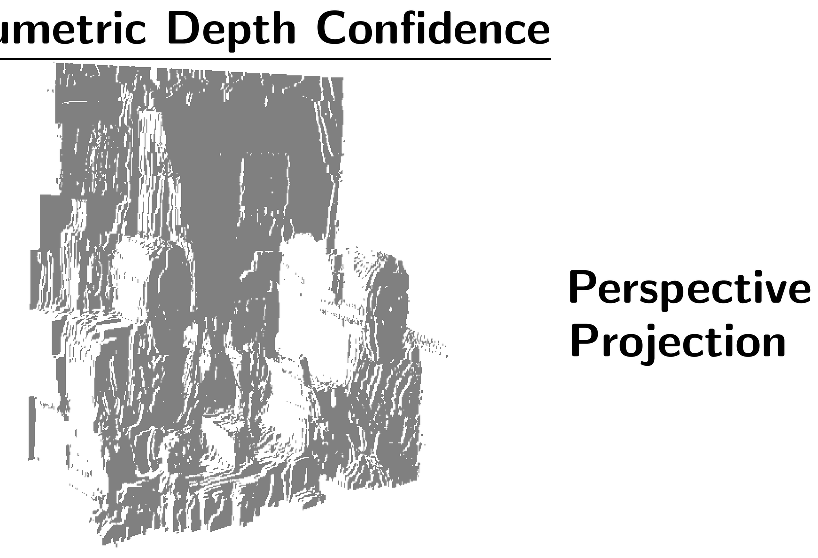


(b) Newspaper.

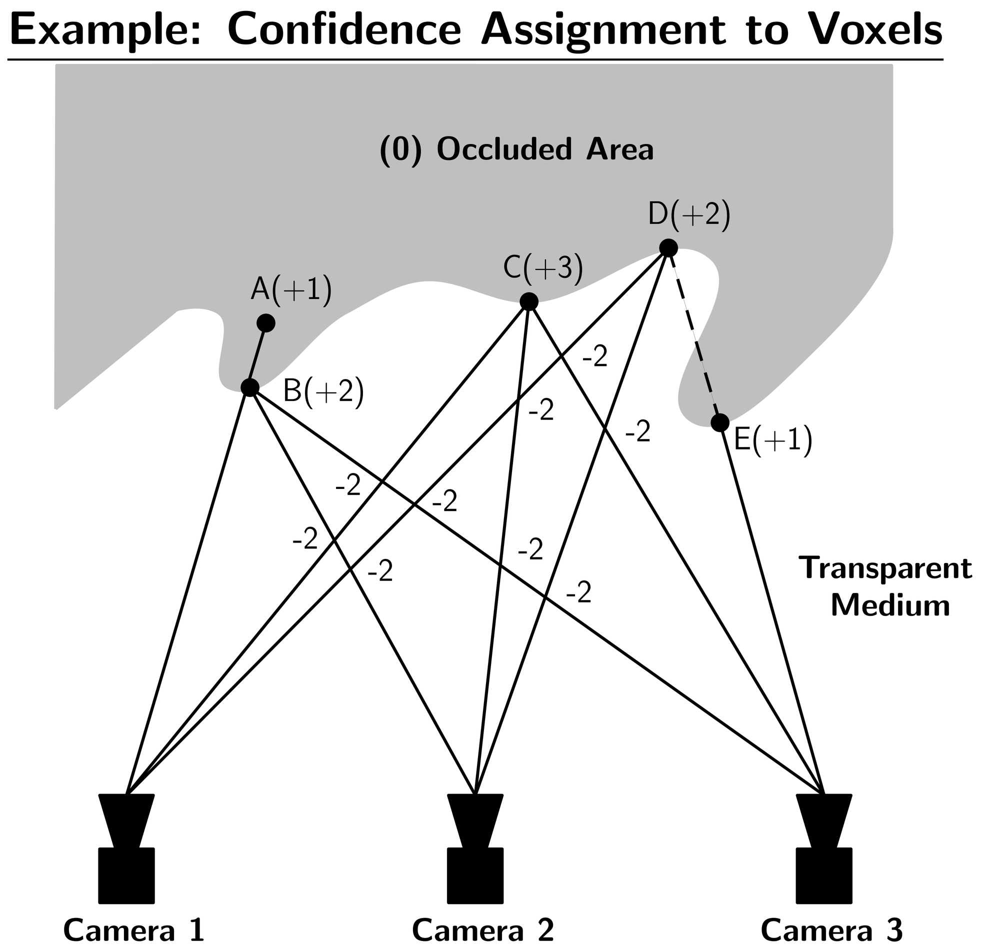
2 APPROACH

Estimated Depth Maps

Volumetric Depth Confidence

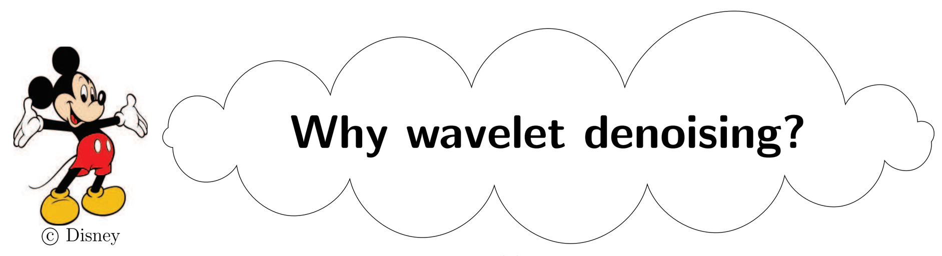


Example: Confidence Assignment to Voxels



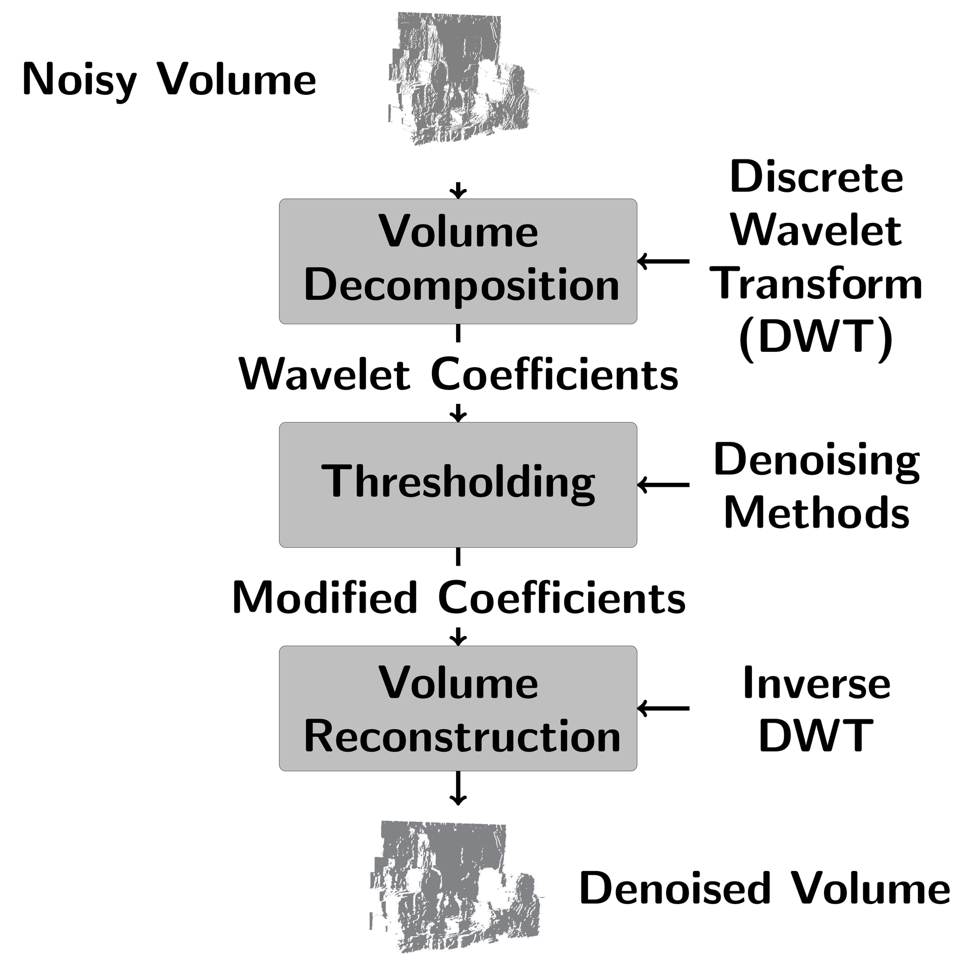
- Each mapped depth pixel from a viewpoint contributes **+1** as confidence for a voxel
- Each occluded pixel from a viewpoint does not change the confidence for a voxel
- Each ray traversing in a transparent voxel contributes **-1** as confidence for a voxel

3 3D WAVELET DENOISING



- It can create sparse coefficients and spreads out i.i.d. noise equally among all the coefficients
- It can distinguish between signal and noise efficiently

Wavelet Denoising Process



Adaptive Thresholding Using SURE Shrink

Goal: Determine thresholds that remove noise efficiently

- **SURE** (**S**tein's **U**nbiased **R**isk **E**stimator) is used to estimate sub–band adaptive thresholds
- For multivariate normal observations, **SURE** offers an unbiased estimate of the expected squared error of the mean
- Let $\{c_i : i = 1, \ldots, l\}$ be the noisy wavelet coefficients in the j-th sub-band.

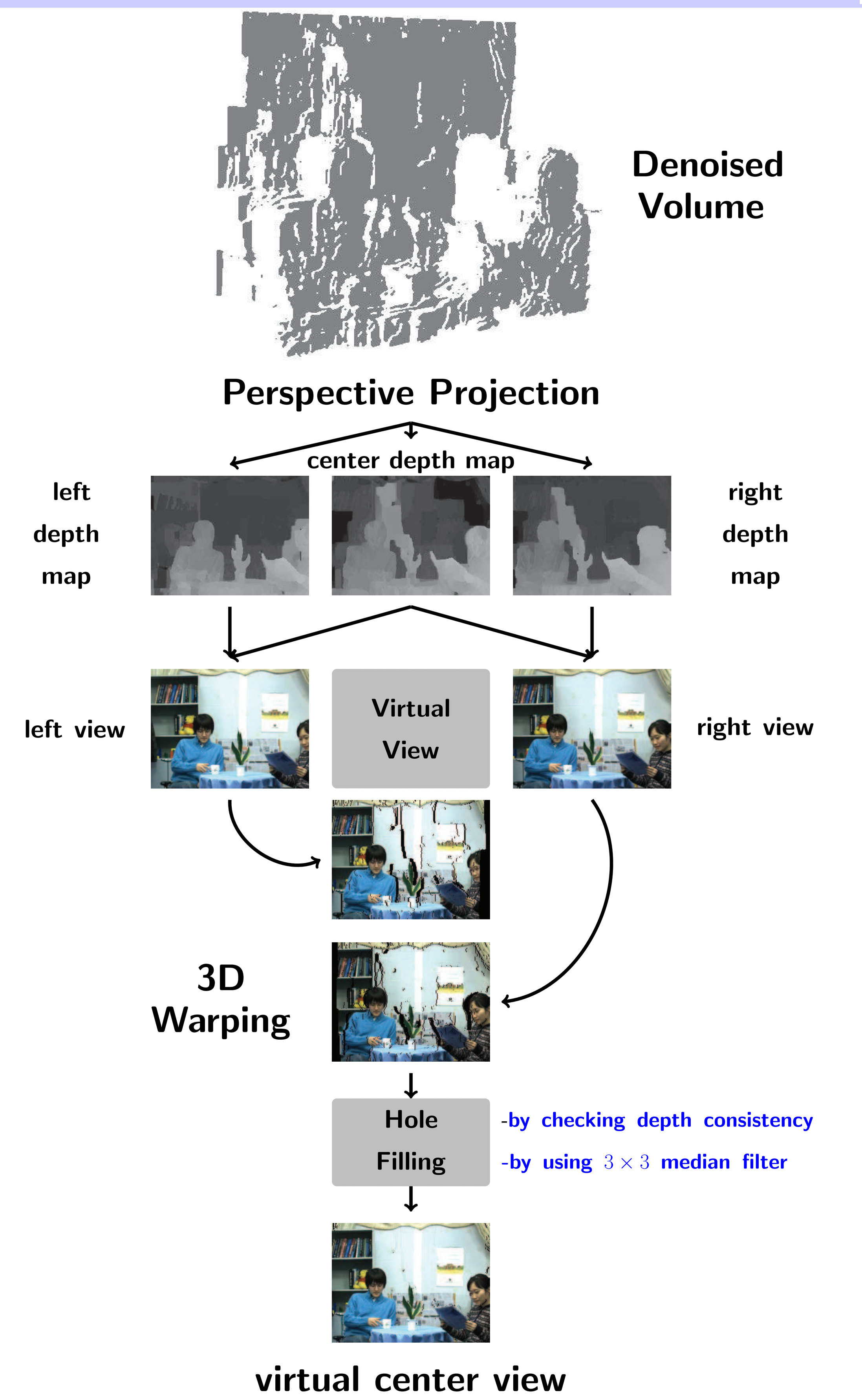
$$\textbf{SURE}(\theta; \underline{c}) = l - 2|\{i : |c_i| < \theta\}| + \sum_{i}^{l} \min(|c_i|, \theta)^2,$$

where θ is a given threshold and $|\cdot|$ denotes the cardinality of a set

- Set the **SURE** threshold θ^S by

$$\theta^S = \arg\min_{\theta} \textbf{SURE}(\theta; \underline{c})$$

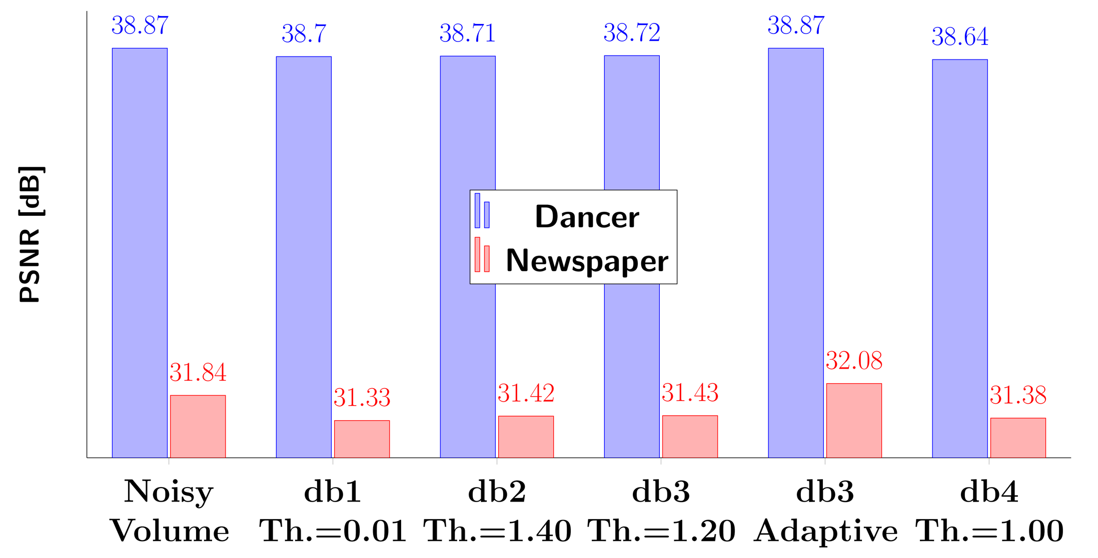
4 VIEW RENDERING



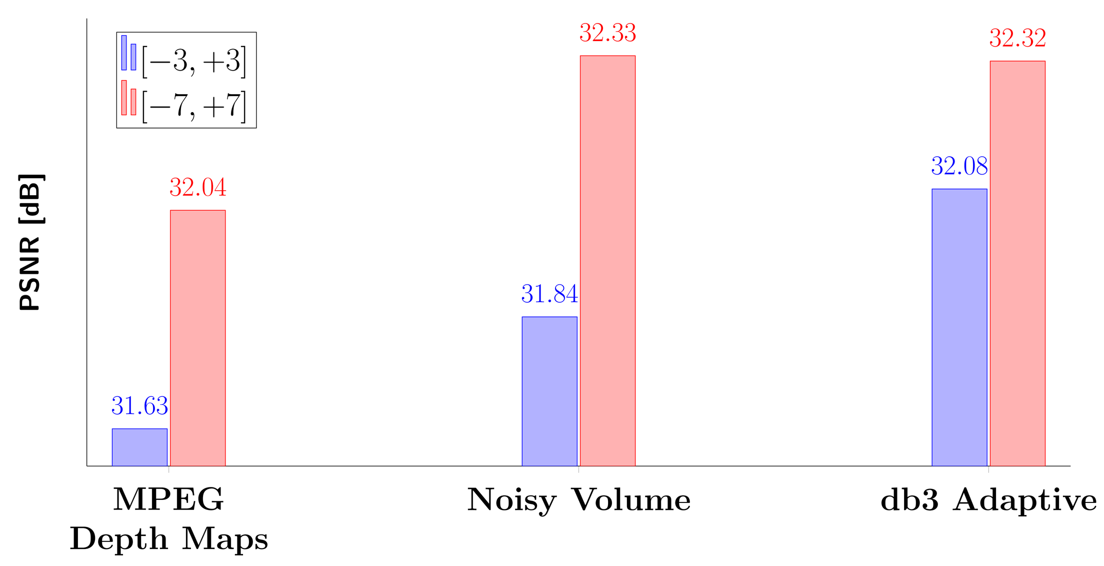
5 EXPERIMENTAL RESULTS

Objective Results

Rendered Views with Confidence Range [-3,3]

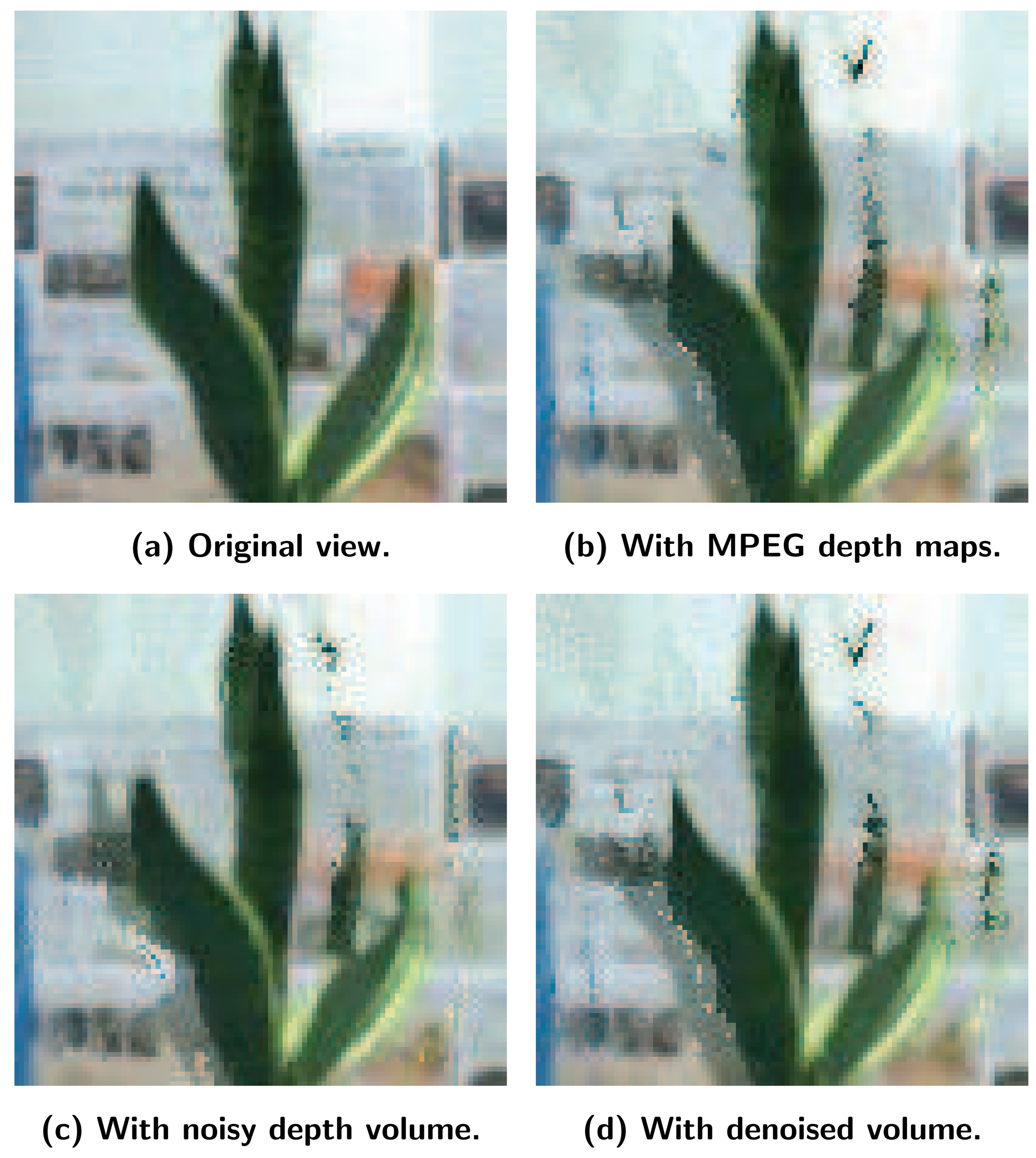


Effect of Confidence Range on Newspaper Rendered Views



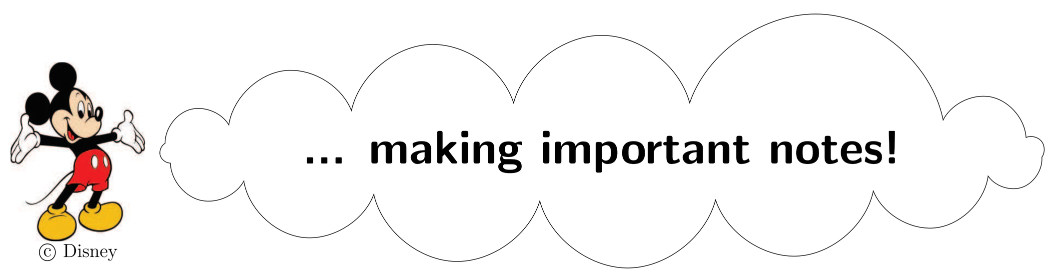
Subjective Results

Rendered views of Newspaper with Confidence Range [-7,+7]



(a) Original view. (b) With MPEG depth maps.

(c) With noisy depth volume. (d) With denoised volume.



- Adaptive thresholding in the 3D wavelet domain improves the quality compared to rendering with MPEG depth maps and noisy volumetric data, respectively
- For synthetic scenes, the improvement is insignificant due to consistent description of the geometry
- Volumetric depth confidence improves rendering results even without wavelet denoising when projecting highest confidence voxels into the camera plane

6 CONCLUSIONS

- Define volumetric depth confidence to handle inconsistent depth estimates
- Use superposition principle to incorporate confidence information from multiple camera views
- Denoise volumetric depth confidence by using adaptive 3D wavelet thresholding
- Improve the visual quality of rendered views by using the denoised volumetric depth confidence