

Motivation

Real-time large-scale 3D reconstruction:

- Global pose optimization to reduce drift
- Usually no surface update on pose changes



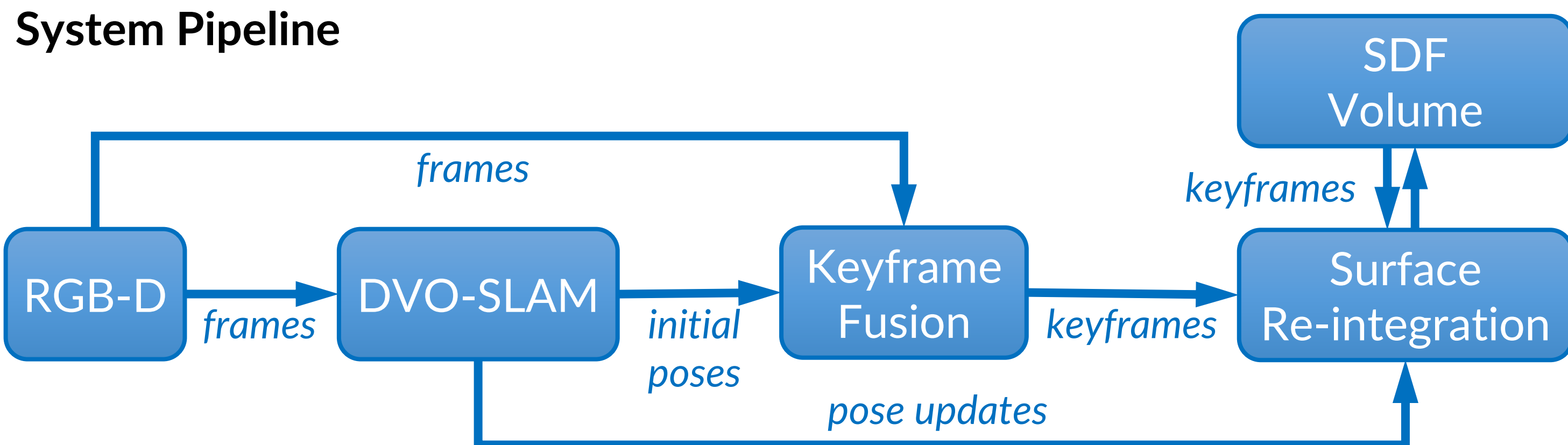
Goal: correct 3D surface on-the-fly on pose changes

Contributions

- Efficient on-the-fly surface correction for large-scale dense 3D reconstruction (single GPU)
 - Keyframe fusion of RGB-D frames using different keyframe strategies
 - Re-integrate fused keyframes into sparse SDF volume on pose updates
 - Efficient re-integration strategy: reduced host-GPU-streaming
 - 93% more efficient than state-of-the-art (equivalent surface quality)
- Combination with dense Visual SLAM system (CPU)

3D Reconstruction System

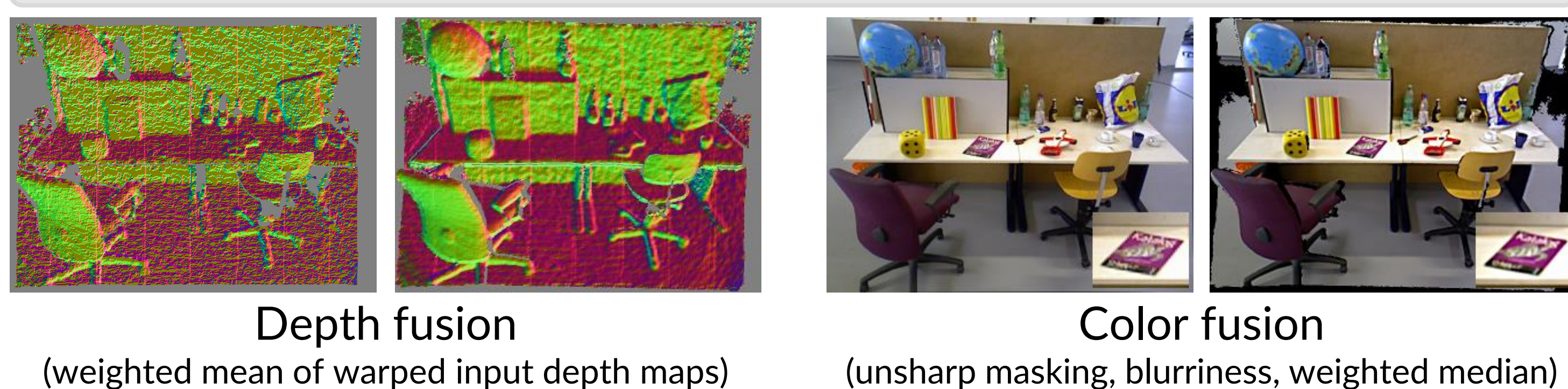
System Pipeline



DVO-SLAM: Dense Visual RGB-D SLAM [1]

- Frame-to-(key)frame tracking using robust dense visual odometry
- Loop closure detection and continuous pose graph optimization

Keyframe Fusion



Efficient Online Surface Re-Integration

Keyframe Strategies

- Selection of independent keyframes for fusion → number of fused frames per keyframe k
- Strategies: Constant, DVO, Distance, Overlap

On-the-fly Surface Correction

- Integrate keyframes into SDF volume with original poses
- On DVO-SLAM pose graph updates:
 - Select m changed keyframes for re-integration
 - De-integrate keyframes at original poses
 - Re-integrate on-the-fly with updated poses

Re-integration Strategy

- BundleFusion [2] strategy: select m most-moved frames
- Better: select group of most-moved m consecutive keyframes

$$j^* = \operatorname{argmax}_{j \in [1, K-m+1]} \sum_{i=j}^{j+m-1} \|st_i - st'_i\|$$

→ Significantly reduced GPU-host-streaming!

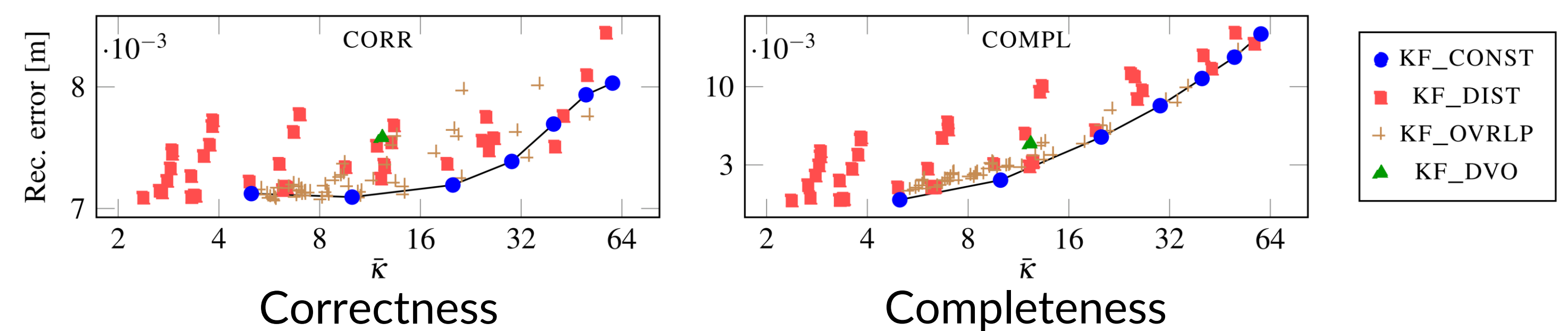
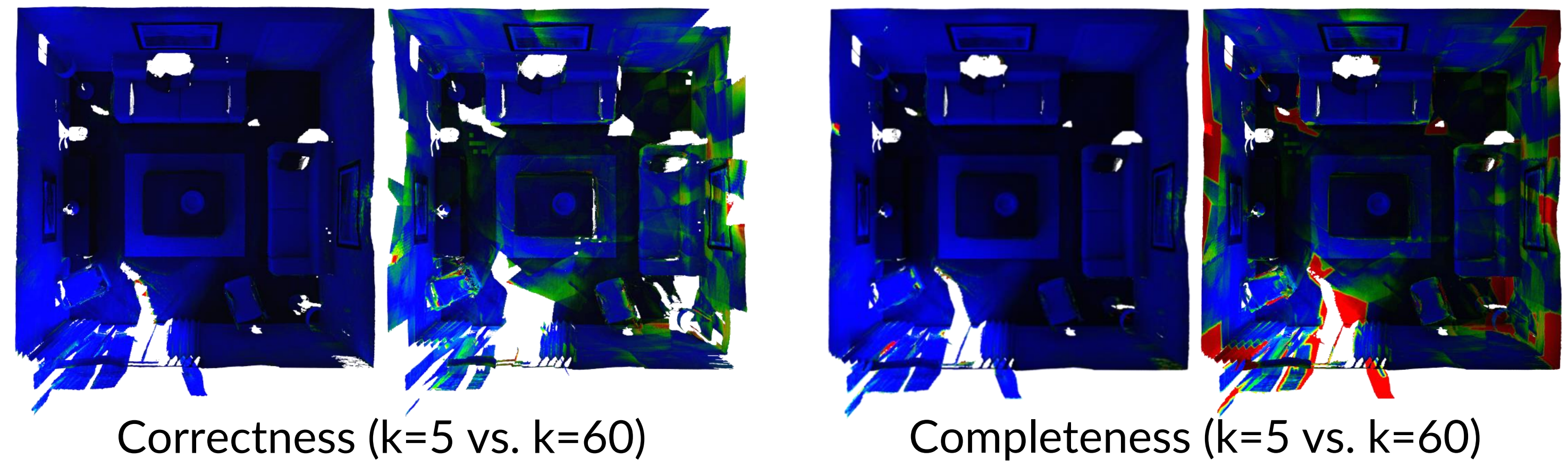
- Example: BundleFusion (12, 8, 13, 5, 3) vs. ours (4 to 8)

Frame	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Distance	1	3	4	3	5	4	1	7	2	1	1	8	6	2	0
Distance (sum)			16	19	17	20	19	15	12	19	18	18	17		

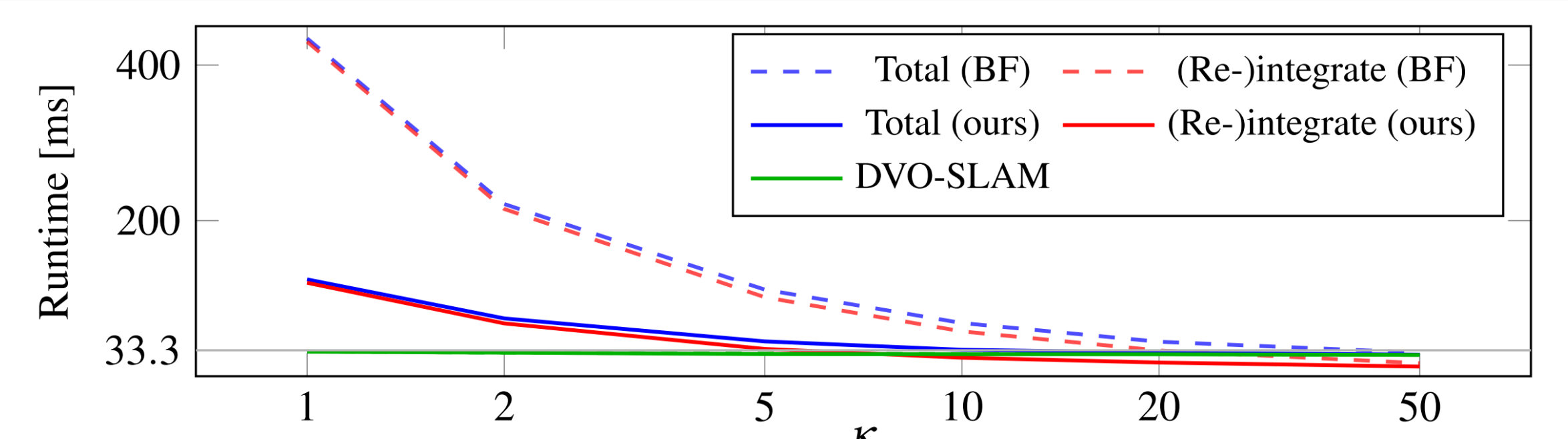
Evaluation and Experimental Results

Surface Completeness/Correctness vs. Frames per Keyframe

AUG_ICL/Liv1



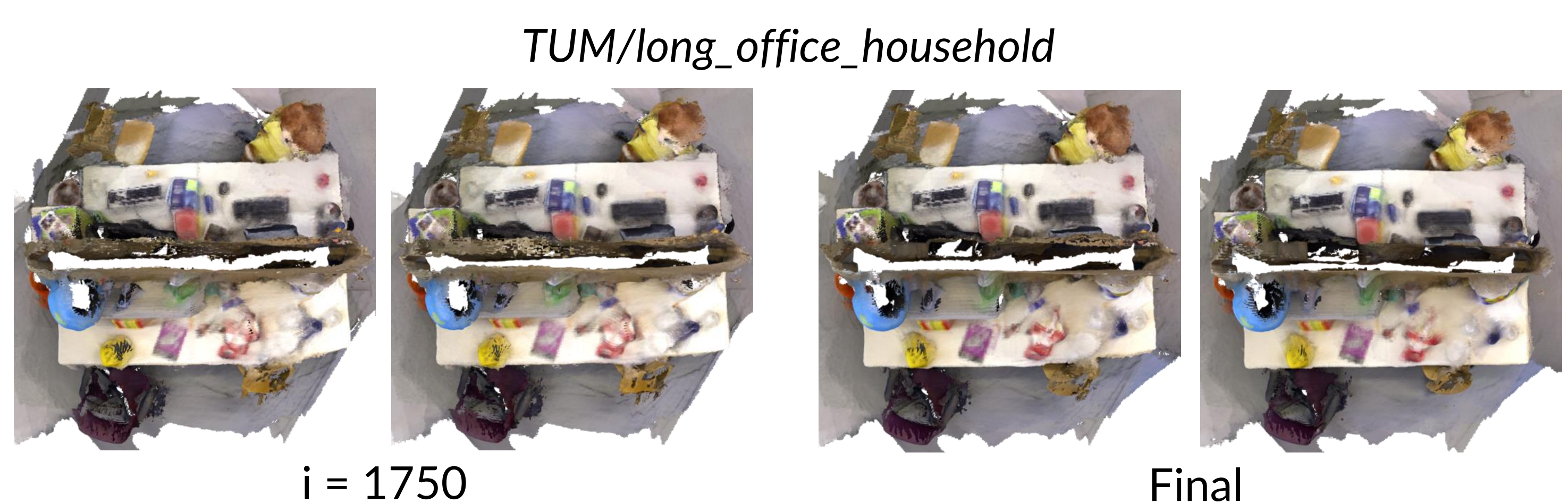
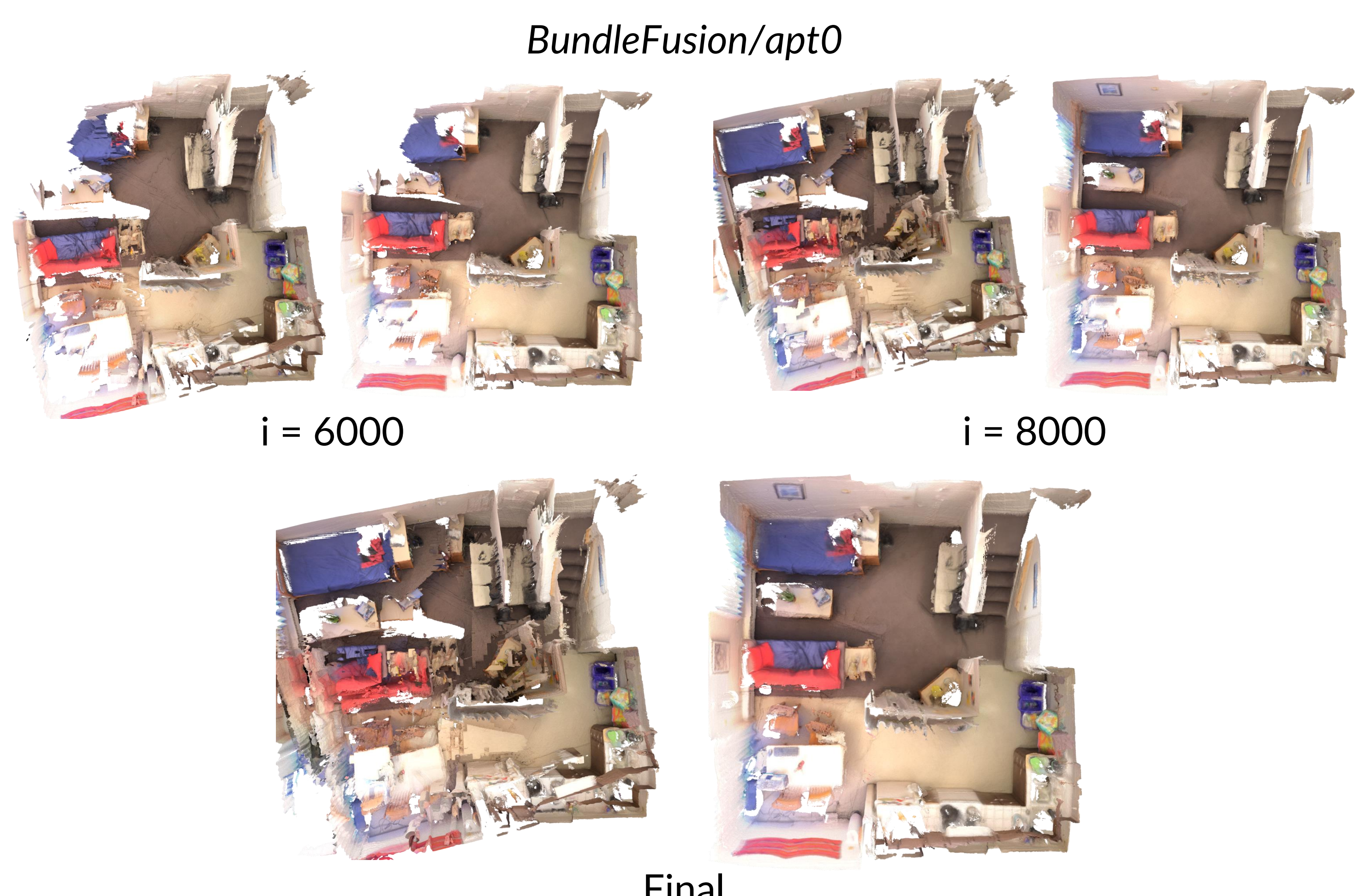
Runtime Evaluation



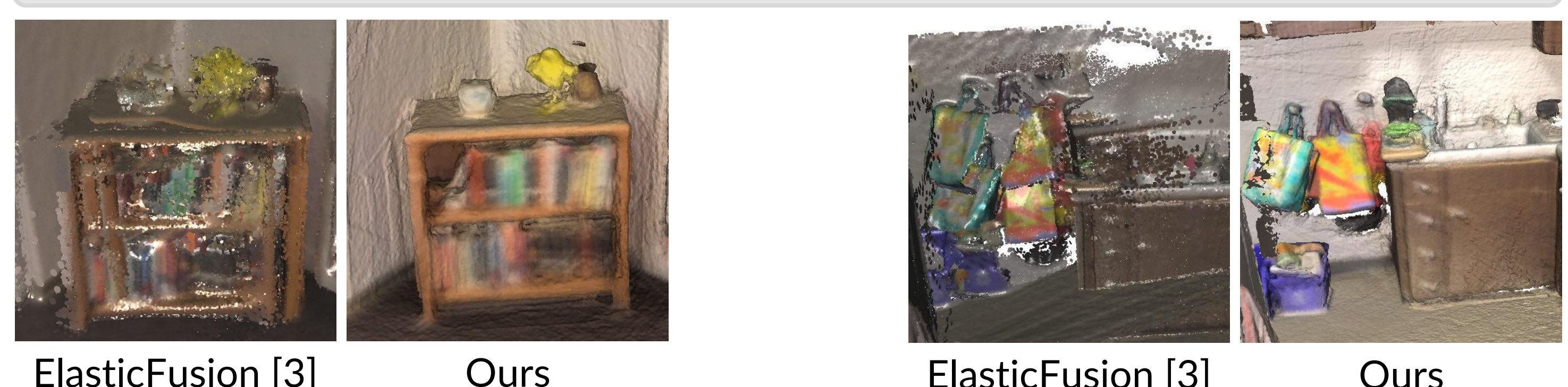
93% more efficient compared to BundleFusion [2] ($k=20, m=5$)

Qualitative Results: On-the-fly Surface Re-integration

Without (left) and with (right) online surface correction



Qualitative Comparison: ElasticFusion [3]



References

- [1] C. Kerl, J. Sturm, D. Cremers. *Dense Visual SLAM for RGB-D Cameras*. IROS 2013.
- [2] A. Dai, M. Nießner, M. Zollhöfer, S. Izadi, C. Theobalt. *BundleFusion: Real-time Globally Consistent 3D Reconstruction using On-the-fly Surface Re-integration*. TOG 2017.
- [3] T. Whelan, S. Leutenegger, R.F. Salas-Moreno, B. Glocker, A.J. Davison. *ElasticFusion: Dense SLAM Without A Pose Graph*. RSS 2015.