Plane-Based Optimization of Geometry and Texture for RGB-D Reconstruction of Indoor Scenes

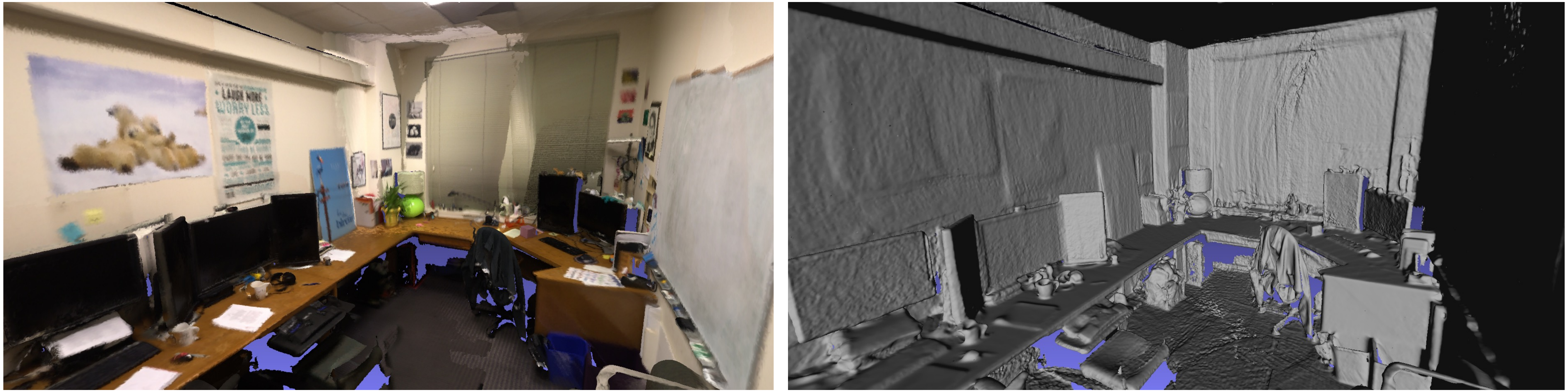
Chao Wang, Xiaohu Guo

University of Texas at Dallas

3DV 2018

Models from online 3D reconstruction

- Dense and noisy model with blurry textures, artifacts, misalignment



2.9M vertices, 5.6M faces, 6K Frames
BundleFusion in TOG'17 [Dai et al.]

Current plane-based optimization methods

- Work on entire building framework or only large planar areas

RAPTER in Siggraph’15 [Monszpart et al.]

3DLite in TOG’17 [Huang et al.]

Our method

- Generates lightweight textured mesh with all geometry objects
- Keeps important sharp features

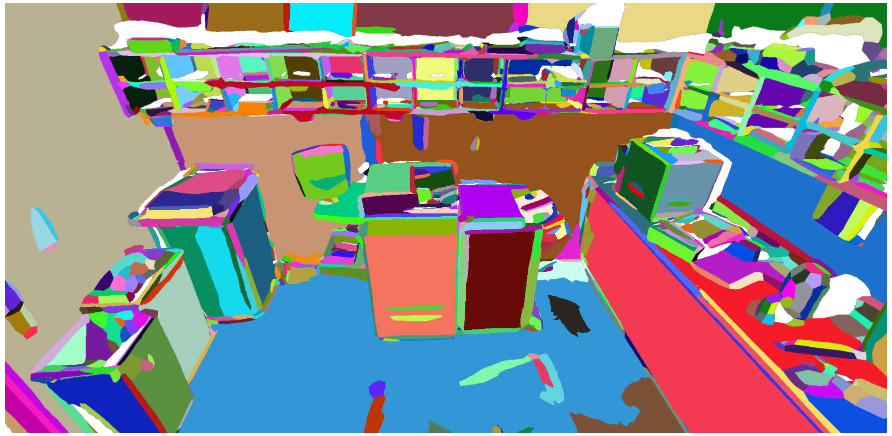
Input dense model by
BundleFusion in TOG'17 [Dai et al.]

3DLite in TOG'17 [Huang et al.]

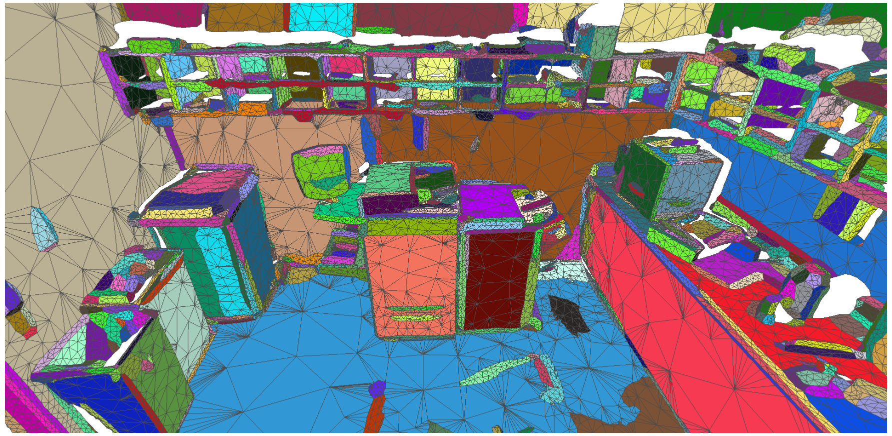
Ours

Overview

Input: RGB-D sequence and dense mesh

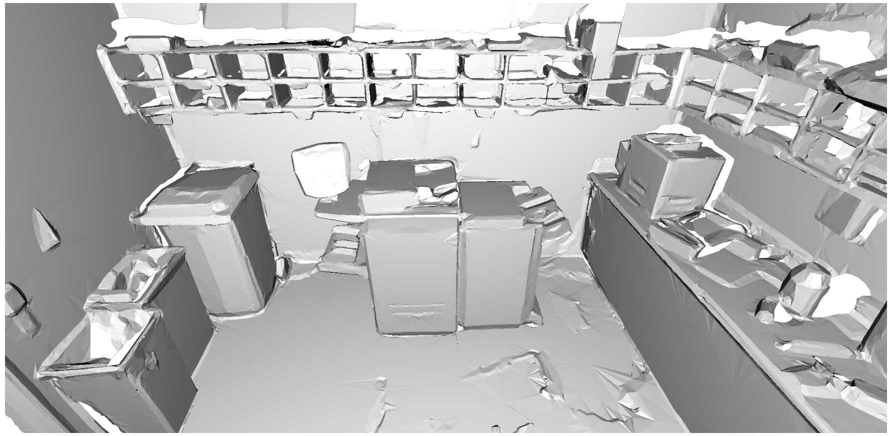


1. Planar partition



2. Mesh simplification based on planes

3. Plane, texture and pose optimization



4. Geometry optimization

Overview

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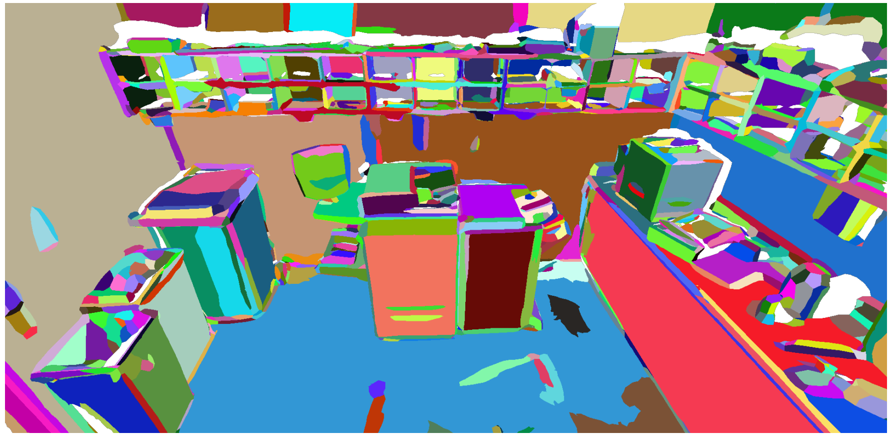

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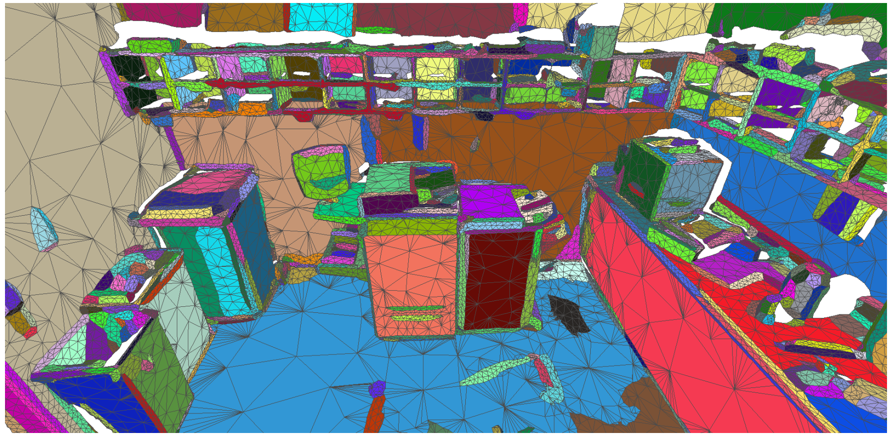

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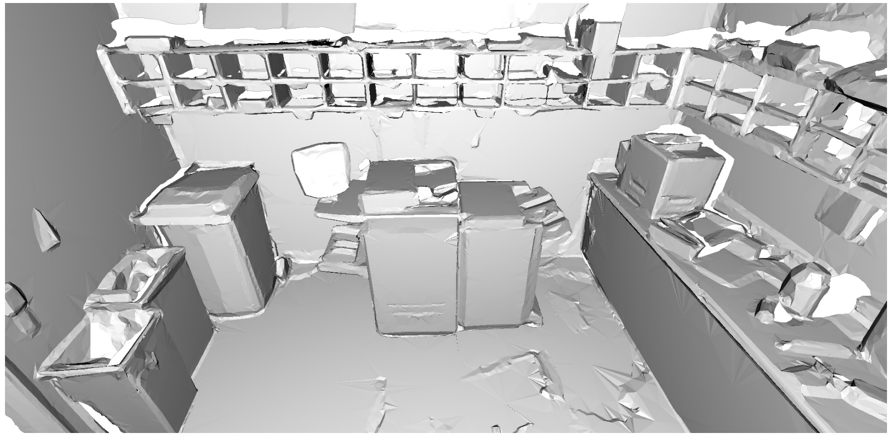

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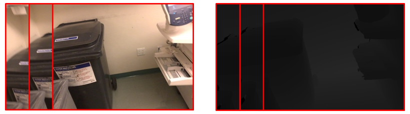

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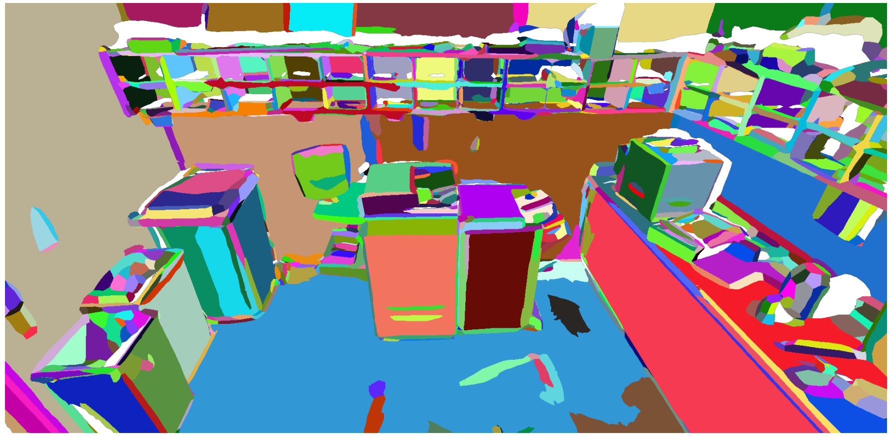

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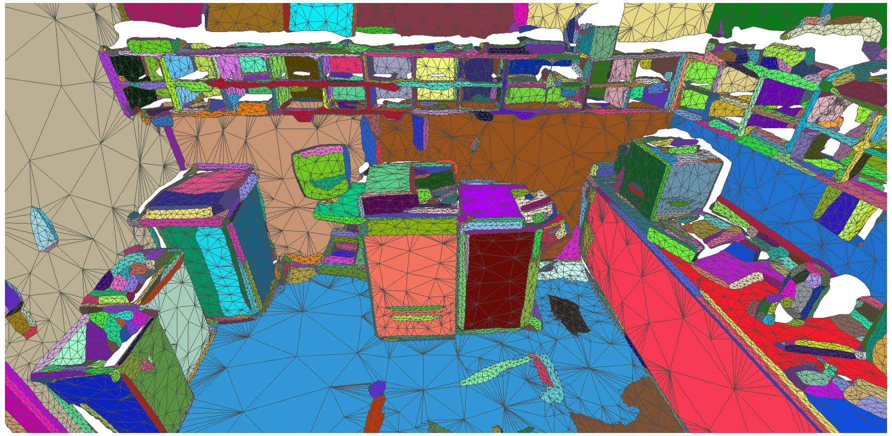

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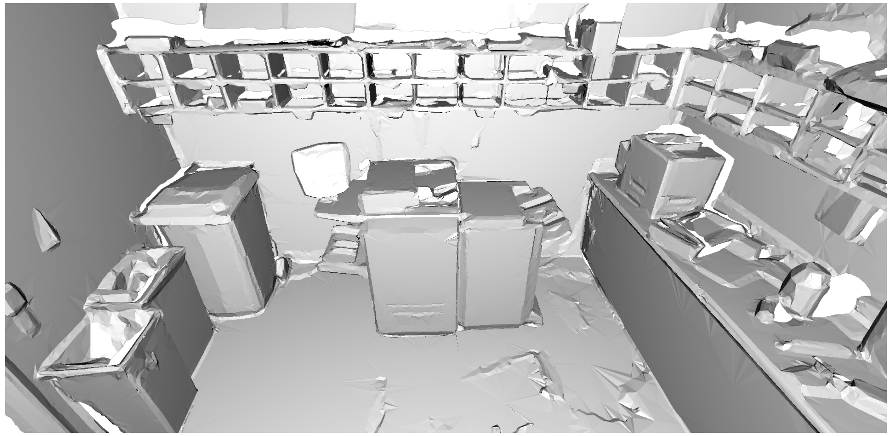

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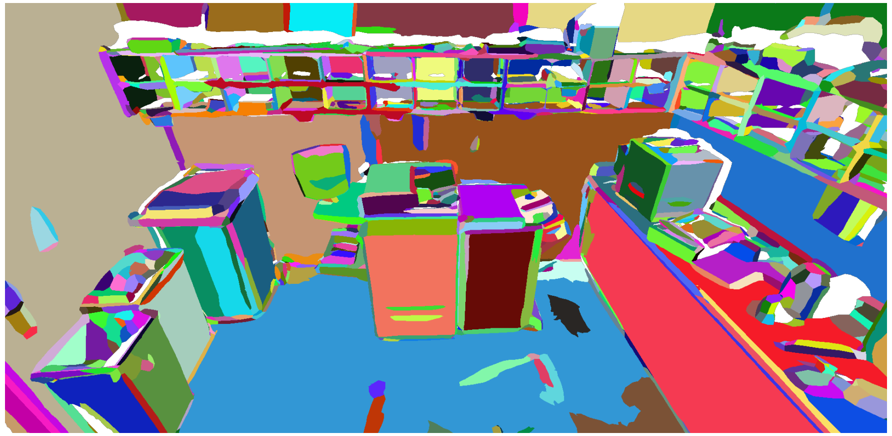

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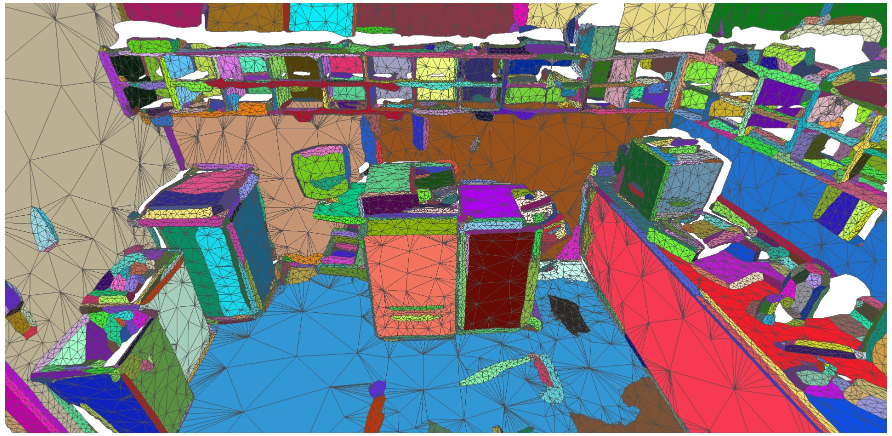

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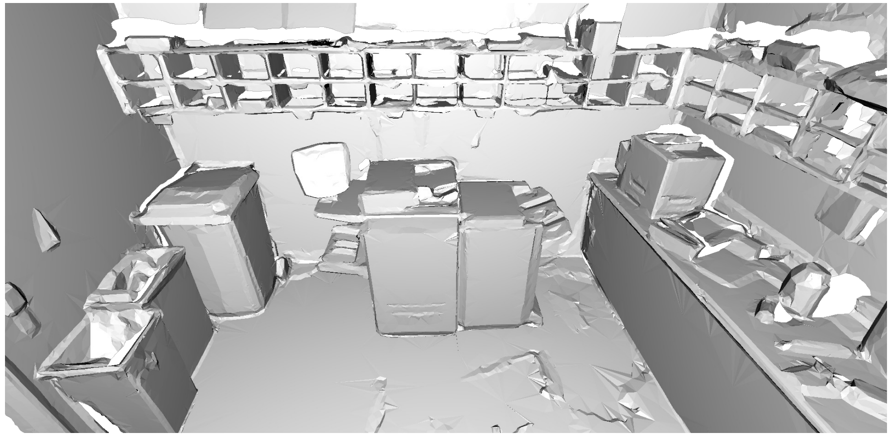

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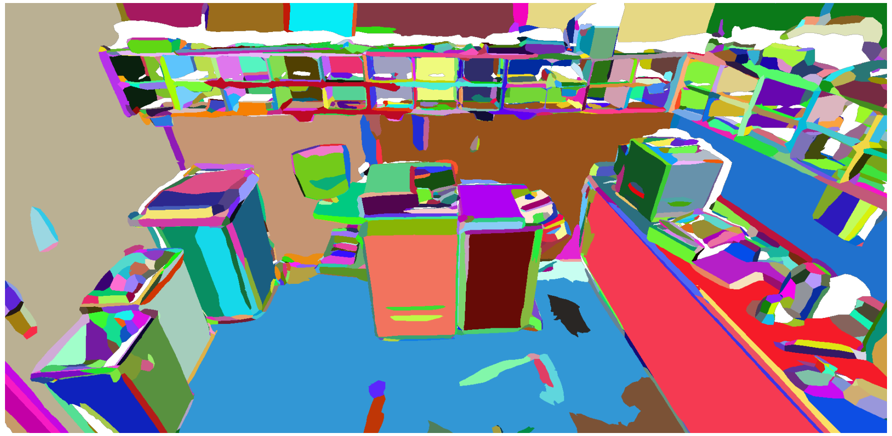

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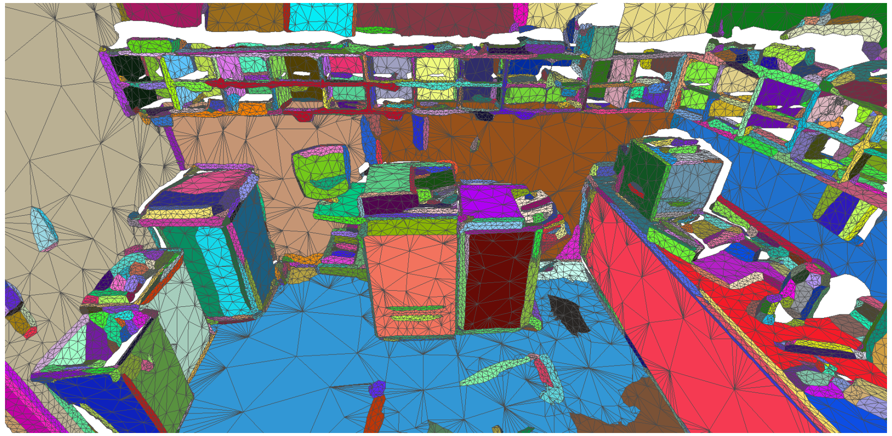

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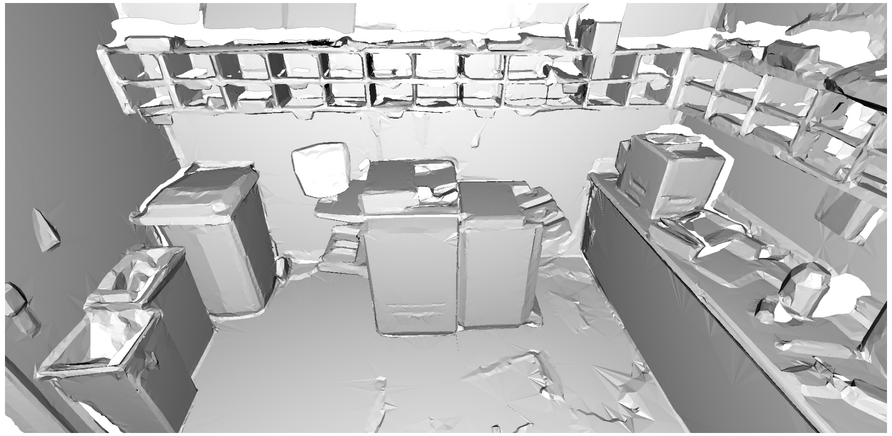
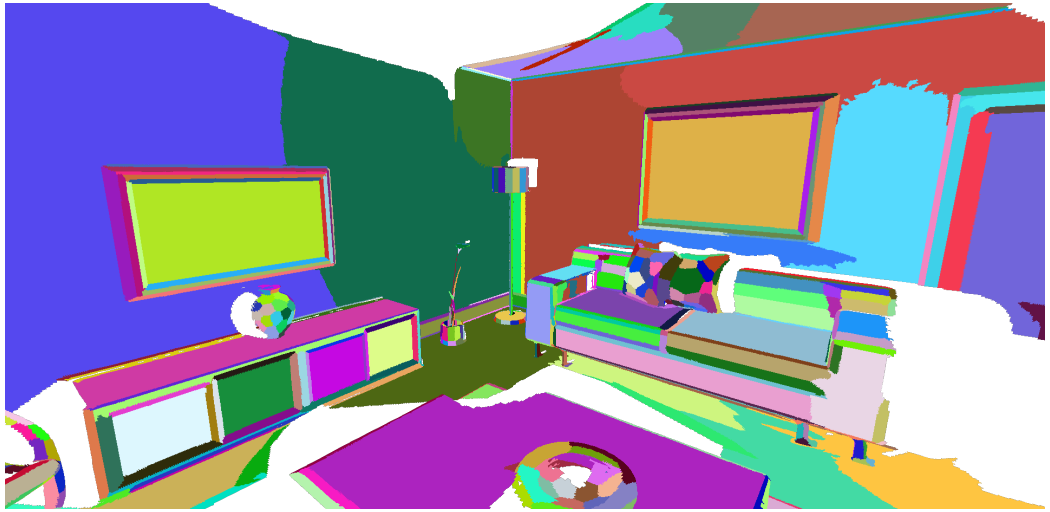


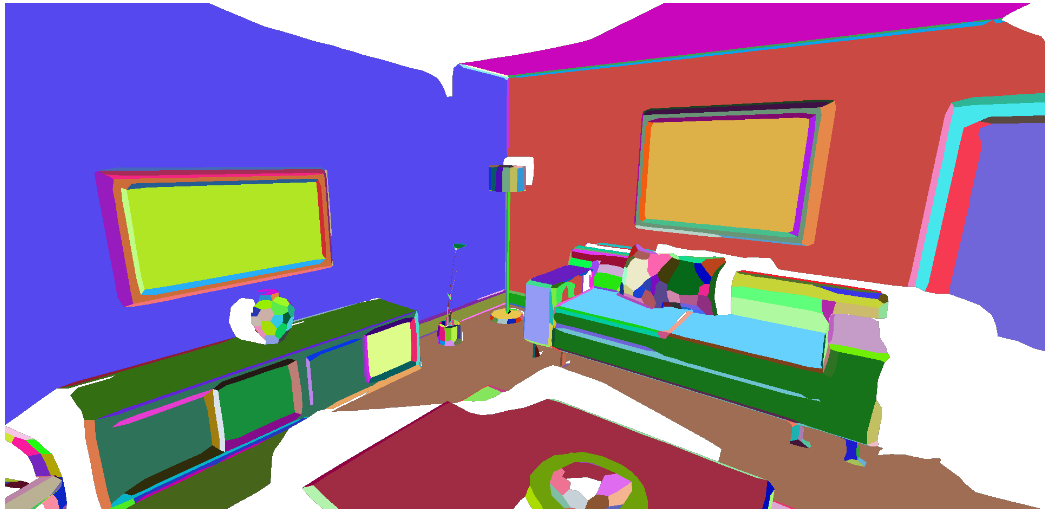
4. Geometry optimization

1. Planar partition

- PCA-energy-based surface partition algorithm [TVCG'17 by Cai et al.]
- Merge neighbor planes



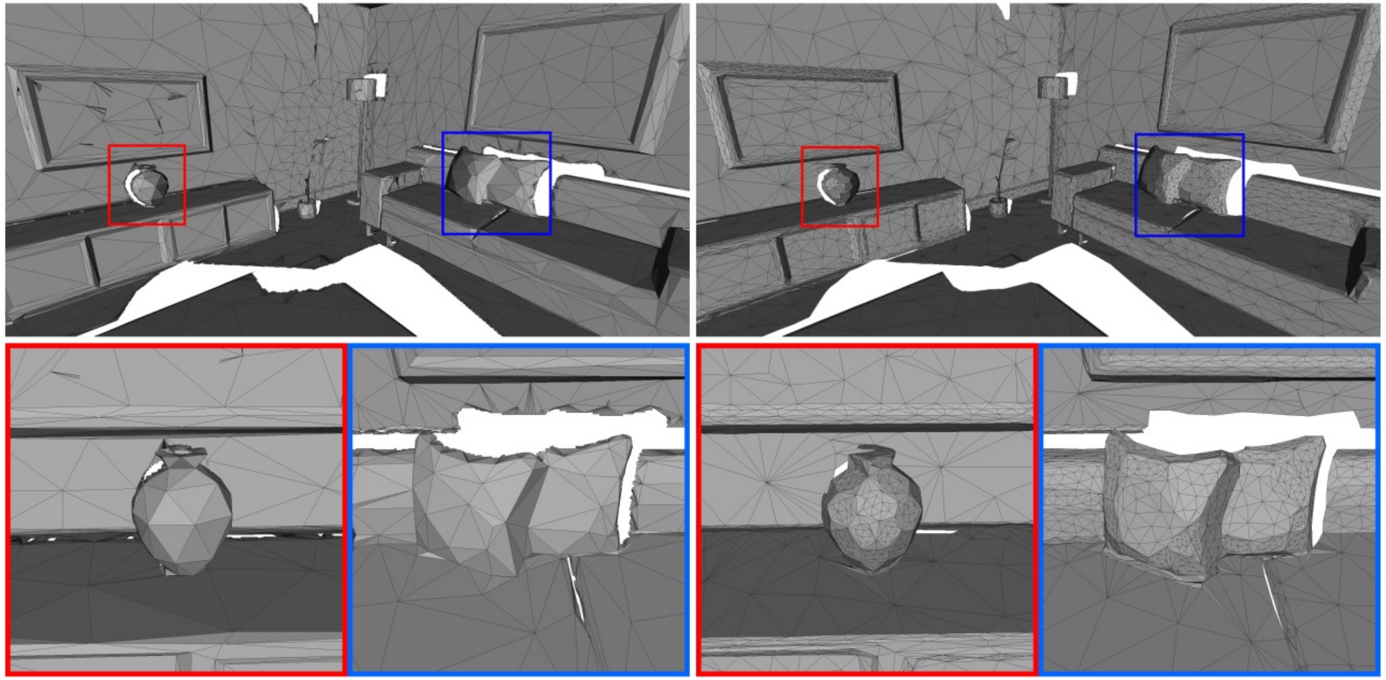
Initial planes



Refined planes

2. Mesh simplification based on planes

- Simplify mesh based on planes using quadric error metric (QEM)
  - 1) Simplify inner plane areas
  - 2) Simplify plane borders



Common QEM | Ours

3. Plane, texture and pose optimization

$$E_{tex}(\mathbf{T},\mathbf{\Phi},\mathbf{C},\mathbf{F}) = \underbrace{E_c(\mathbf{T},\mathbf{\Phi},\mathbf{C},\mathbf{F})}_{\text{Photometric consistency}} + \lambda_1 \underbrace{E_p(\mathbf{\Phi})}_{\text{Plane constraint}} + \lambda_2 \underbrace{E_s(\mathbf{F})}_{\text{Image offset constraint}}$$

$\mathbf{T}$: camera poses

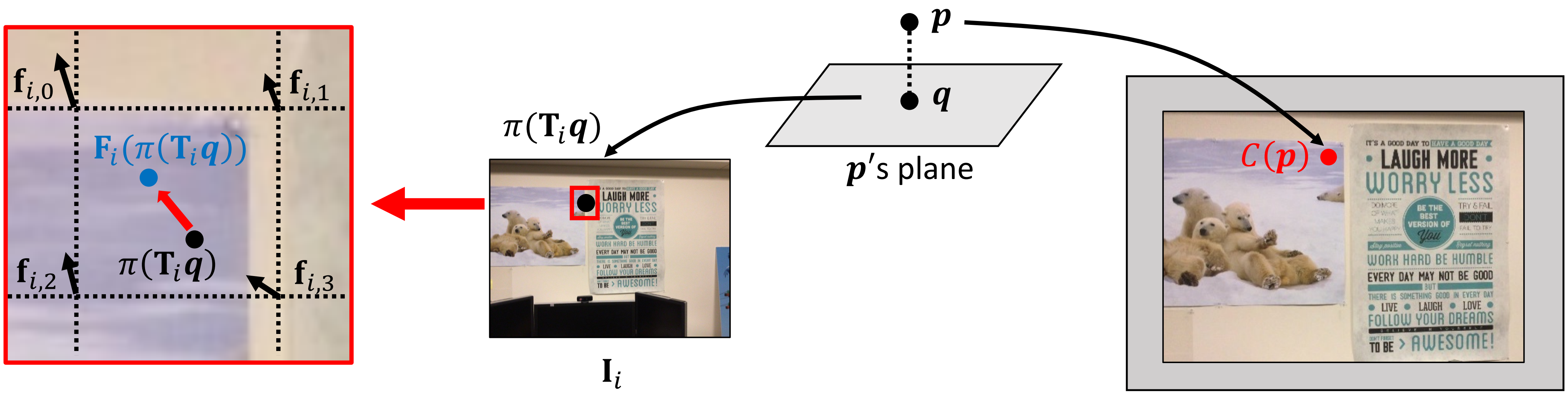
$\mathbf{\Phi}$: plane parameters

$\mathbf{C}$: texture image pixel (texel) colors

$\mathbf{F}$: image distortion offsets

3. Plane, texture and pose optimization

$$E_c(\mathbf{T}, \mathbf{\Phi}, \mathbf{C}, \mathbf{F}) = \sum_{\boldsymbol{i}} \sum_{\boldsymbol{p}} ||C(\boldsymbol{p}) - \mathbf{I}_i(\mathbf{F}_i(\pi(\mathbf{T}_i \boldsymbol{q})))||^2$$



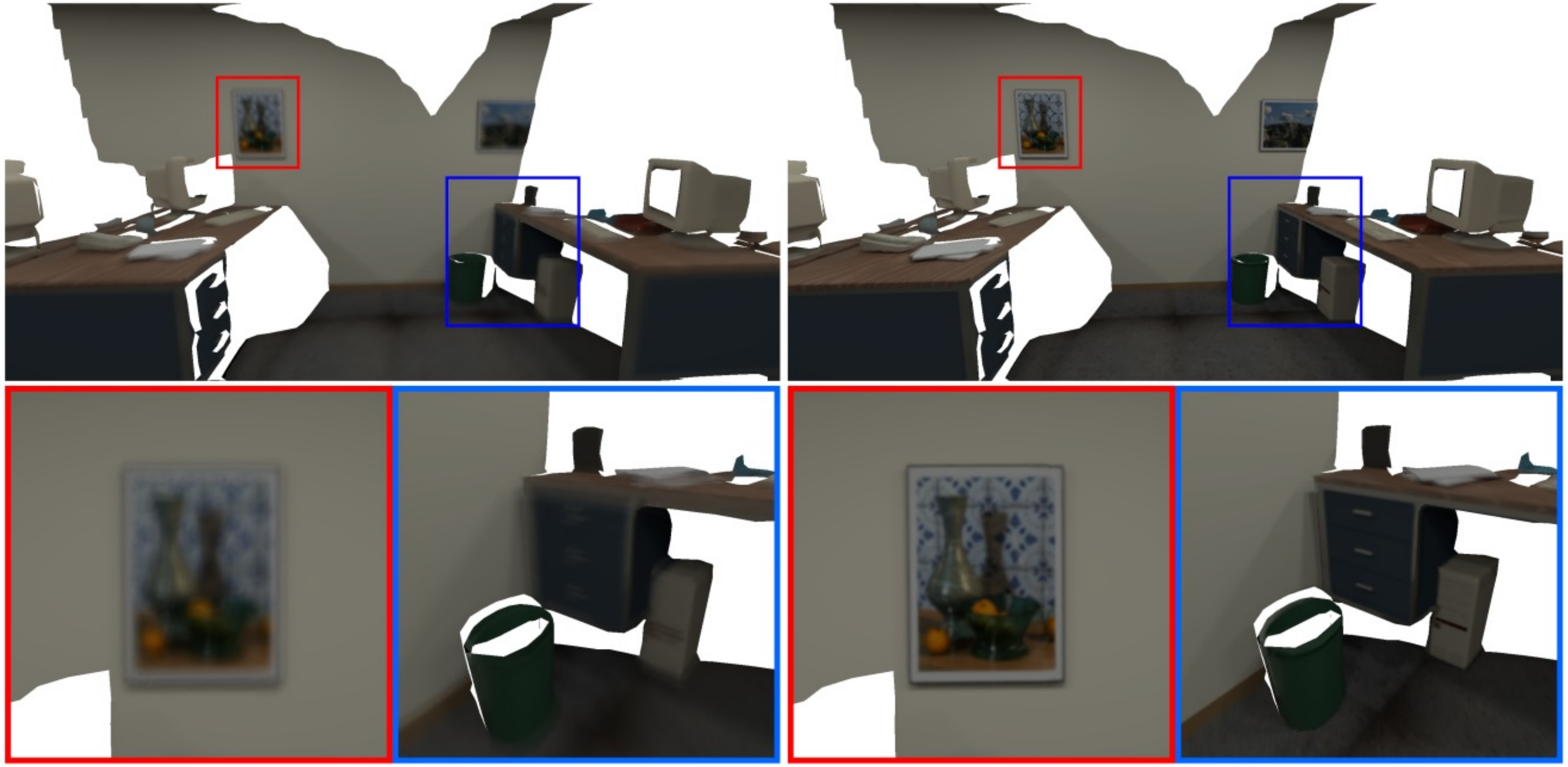
Correction on color image
[TOG'14 by Zhou et al.]

Color image

World space

Texture image

3. Plane, texture and pose optimization



Without optimization

With optimization

4. Geometry optimization

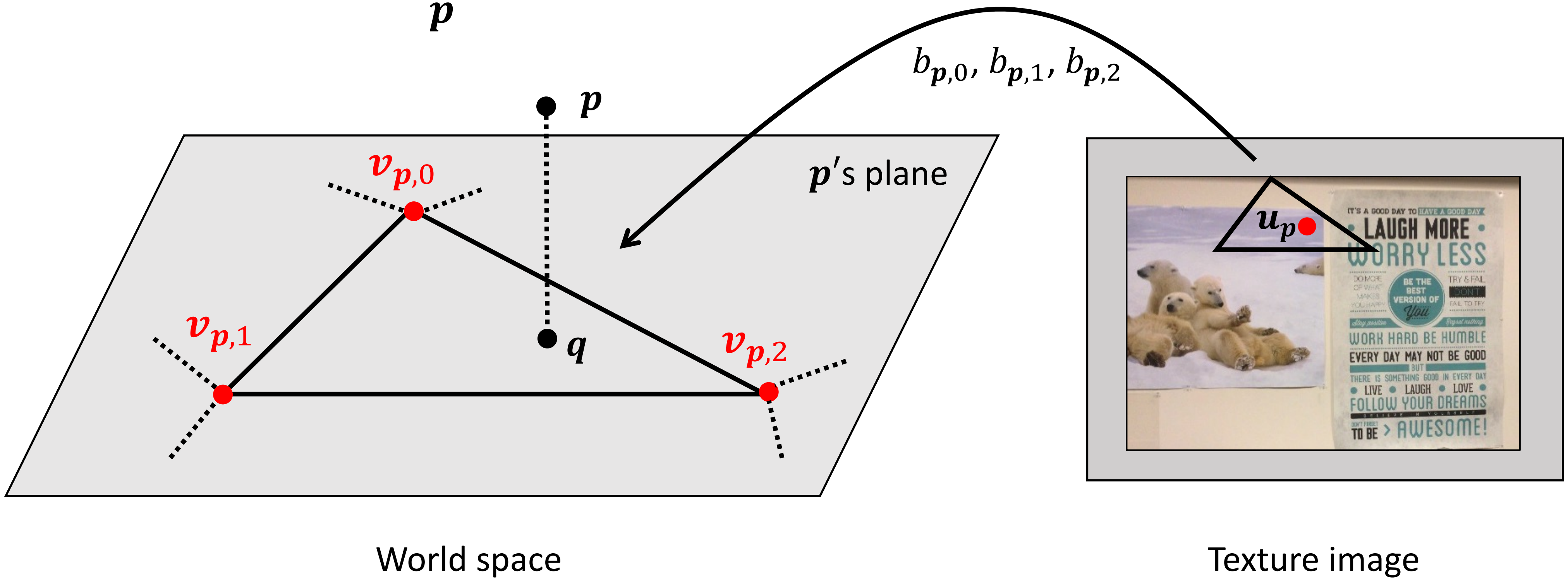
$$E_{vert}(\mathbf{V}) = E_g(\mathbf{V}) + \lambda_3 E_t(\mathbf{V})$$

Geometry-plane consistency

Regularization based on neighbor connectivity

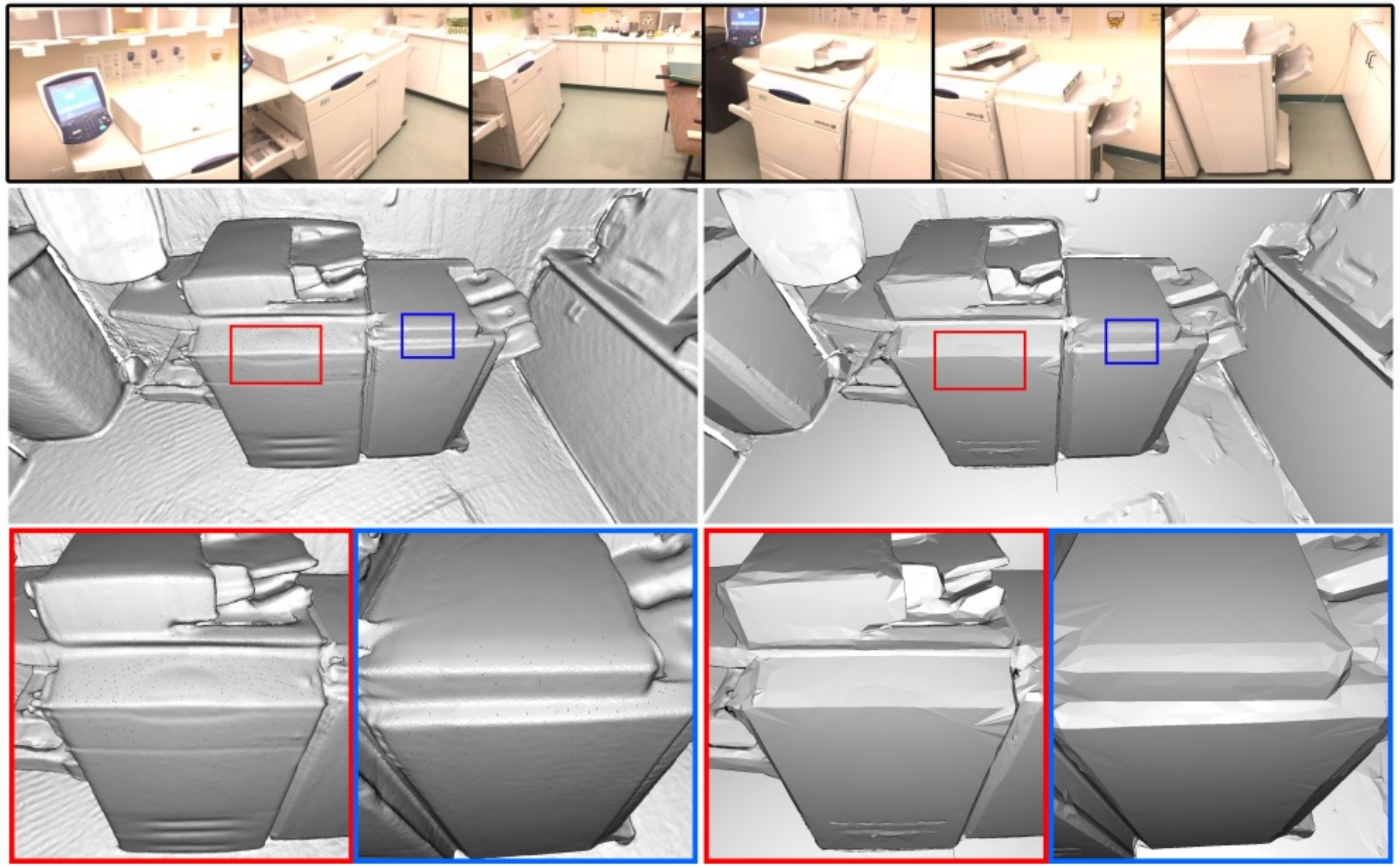
4. Geometry optimization

$$E_g(\mathbf{V}) = \sum_{\boldsymbol{p}} ||\boldsymbol{q} - (b_{\boldsymbol{p},0}\boldsymbol{v}_{\boldsymbol{p},0} + b_{\boldsymbol{p},1}\boldsymbol{v}_{\boldsymbol{p},1} + b_{\boldsymbol{p},2}\boldsymbol{v}_{\boldsymbol{p},2})||^2$$



$b_{\boldsymbol{p},0}, b_{\boldsymbol{p},1}, b_{\boldsymbol{p},2}$: $\boldsymbol{u}_{\boldsymbol{p}}$'s barycentric coordinates inside its triangle on texture image

4. Geometry optimization



Input fused dense mesh

After geometry optimization

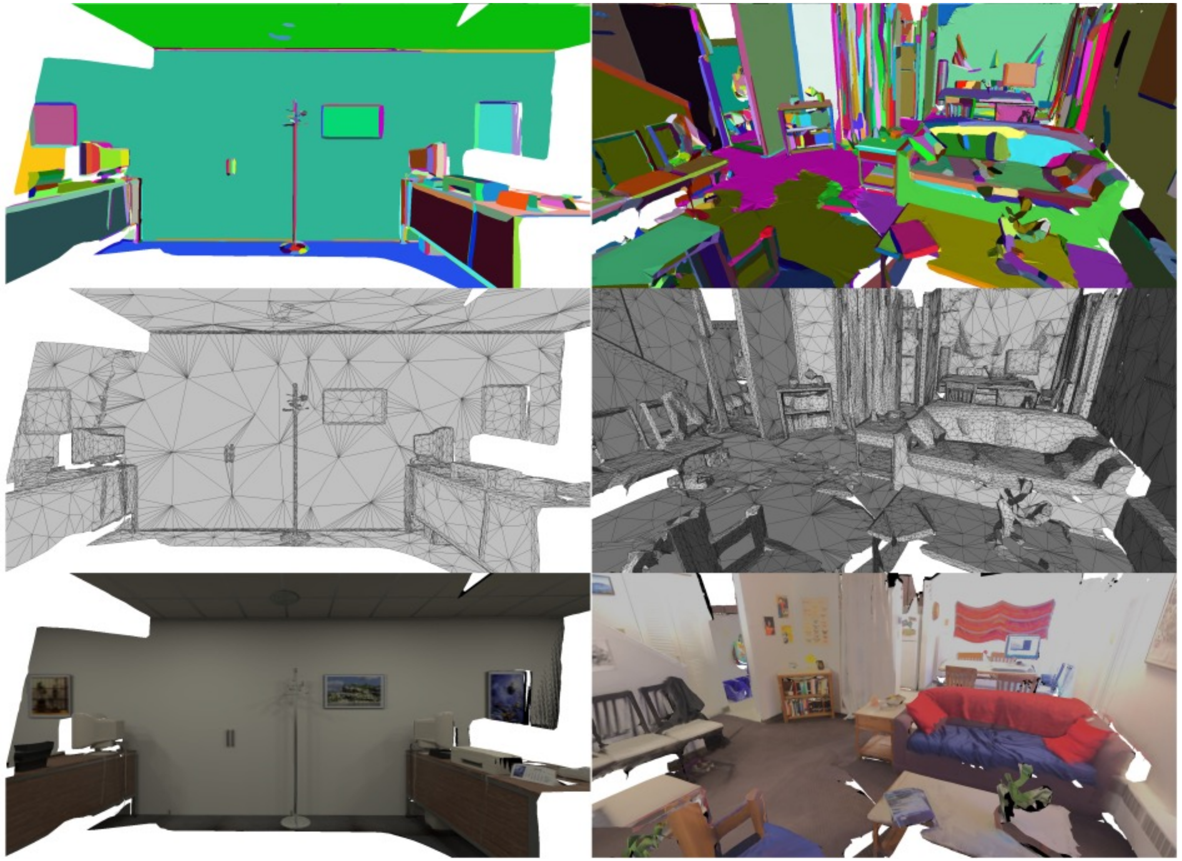
Result

- #faces and #vertices: 1%-3% of original dense model
- Running time: 15 mins/sequence on average of 10 sequences (Only CPU)

Planar partition

Mesh

Texture



Model: ***office0*** **(**from BundleFusion dataset)

3DLite
(42K vertices,
63K faces)

1x speed

BundleFusion
(5.71M vertices, 11.3M faces)

Ours
(68K vertices,
130K faces)

Thank you!