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

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Models from online 3D reconstruction

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

*office0* from BundleFusion dataset (Dai et al., TOG’17)
2.9M vertices, 5.6M faces
Current plane-based optimization methods

• Work on building framework only or large planar areas only

RAPTER (Monszpart et al., Siggraph’15) 3DLite (Huang et al., TOG’17)
Our method

- **Input**: RGB-D sequence and dense mesh reconstructed from it
- **Output**: lightweight, low-polygon mesh with textures

Input dense model by BundleFusion
3.70M vertices, 7.28M faces

Output plane partition and textured mesh
16K vertices, 31K faces
Pros

• Build entire scene by planes without losing details;
• Preserve sharp features;
• Efficient: 10-20 minutes per model instead of hours in state-of-the-arts on same sequences.

Input dense model by BundleFusion
3.70M vertices, 7.28M faces

Output plane partition and textured mesh
16K vertices, 31K faces
1. Planar partition

- PCA-energy-based surface partition algorithm (Cai et al., TVCG’17)
- Merge neighbor planes
2. Mesh simplification based on planes

• Use quadric error metric (QEM)
  ▪ Simplify inner plane areas first
  ▪ Simplify all plane borders next

Common global QEM  
Ours
3. Plane, texture and pose optimization

$$E_{tex}(T, \Phi, C) = E_c(T, \Phi, C) + \lambda_p E_p(\Phi) + \lambda_t E_t(T, \Phi)$$

**T:** camera poses, each with 6DoF  
**Φ:** plane parameters: 4DoF  
**C:** texture image pixel (texel) colors
Photometric consistency term

\[ E_c(T, \Phi, C, F) = \sum_i \sum_p \| C(p) - I_i(\pi(T_i q)) \|^2 \]

\( p \)’s plane

\( \pi(T_i q) \)

Color image in frame \( i \)

World space

Texture image
Optimization result

No optimization  With optimization
4. Geometry optimization

\[ E_{\text{vert}}(V) = E_g(V) + \lambda_l E_l(V) + \lambda_r E_r(V) \]

- Vertex-plane consistency
- Line constraint
- Regularization based on neighbor connectivity
Vertex-plane consistency

\[ E_g(V) = \sum_p ||q - (b_{p,0}v_{p,0} + b_{p,1}v_{p,1} + b_{p,2}v_{p,2})||^2 \]

\( b_{p,0}, b_{p,1}, b_{p,2}: u_p \)'s barycentric coordinates inside its triangle on texture image
Model: **office0** (from BundleFusion dataset)

- **3DLite**
  - 41k vertices, 63K faces

- **BundleFusion**
  - 5.71M vertices, 11.3M faces

- **Ours**
  - 24k vertices, 42K faces

**1x speed**
Thank you!

Source code can be found in
https://github.com/chaowang15/plane-opt-rgbd