CSfM: Community-based Structure-from-Motion

Hainan Cui, Shuhan Shen, Xiang Gao, Zhanyi Hu
NLPR, Institute of Automation, Chinese Academy of Sciences

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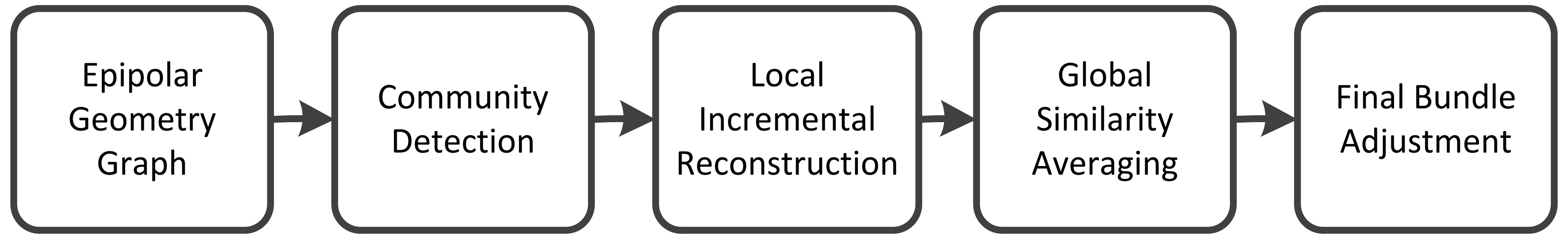
Motivation

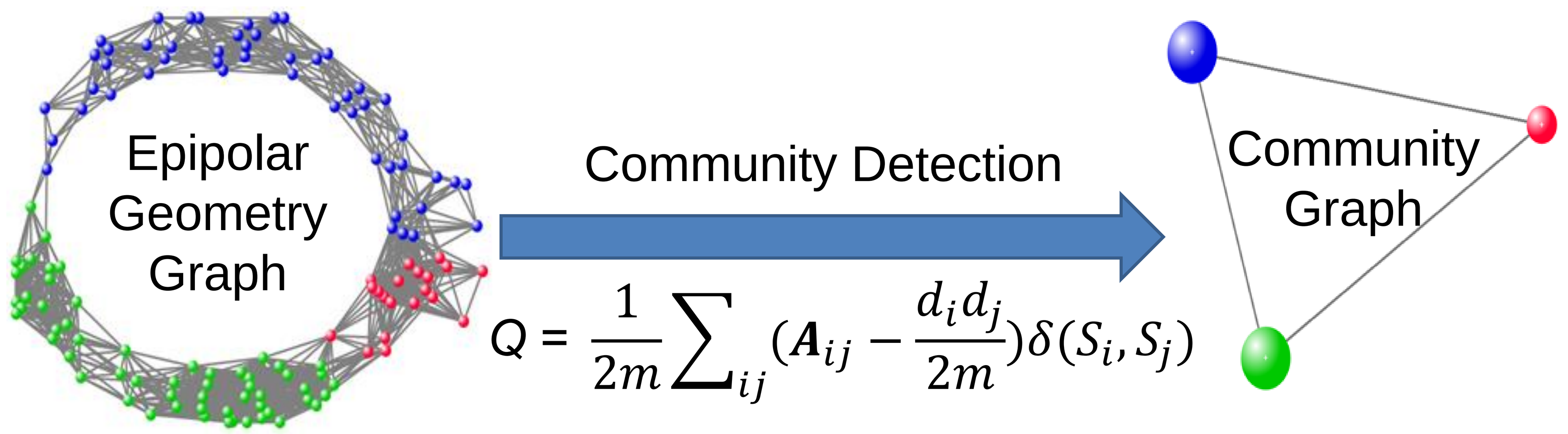
Incremental SfM has advanced in both accuracy and robustness, while it suffers from error accumulation and poor efficiency for large-scale reconstruction. Global SfM is efficient, but is sensitive to the image feature match outliers.

Proposed CSfM pipeline



CSfM inherits the advantages from both manners:
(1) Local incremental reconstruction is robust to feature match outliers;
(2) Global similarity averaging tackles the error accumulation problem.

Community Detection



$$Q = \frac{1}{2m}\sum_{ij}\left(A_{ij} - \frac{d_i d_j}{2m}\right)\delta(S_i, S_j)$$

Clustering the epipolar geometry graph into a community graph:
(1) Each node corresponds to a community;
(2) An edge links two communities when some epipolar edges exist between them.

Global Similarity Averaging

Given the scale factor s_i for each community and the relative scale s_{ij} between two connected communities:

$$s_{ij} = s_j \,/\, s_i \qquad \log(s_{ij}) = \log(s_j) - \log(s_i)$$

Given the rotation $\boldsymbol{R}_i$ for each community and relative rotations $\boldsymbol{R}_{ij}$ in the similarity transformation:

$$\boldsymbol{R}_{ij} = \boldsymbol{R}_j\boldsymbol{R}_i^T \qquad \boldsymbol{w}_{ij} = \boldsymbol{w}_j - \boldsymbol{w}_i$$

Given the translation $\boldsymbol{T}_i$ for each community and relative translations $\boldsymbol{T}_{ij}$ in the similarity transformation:

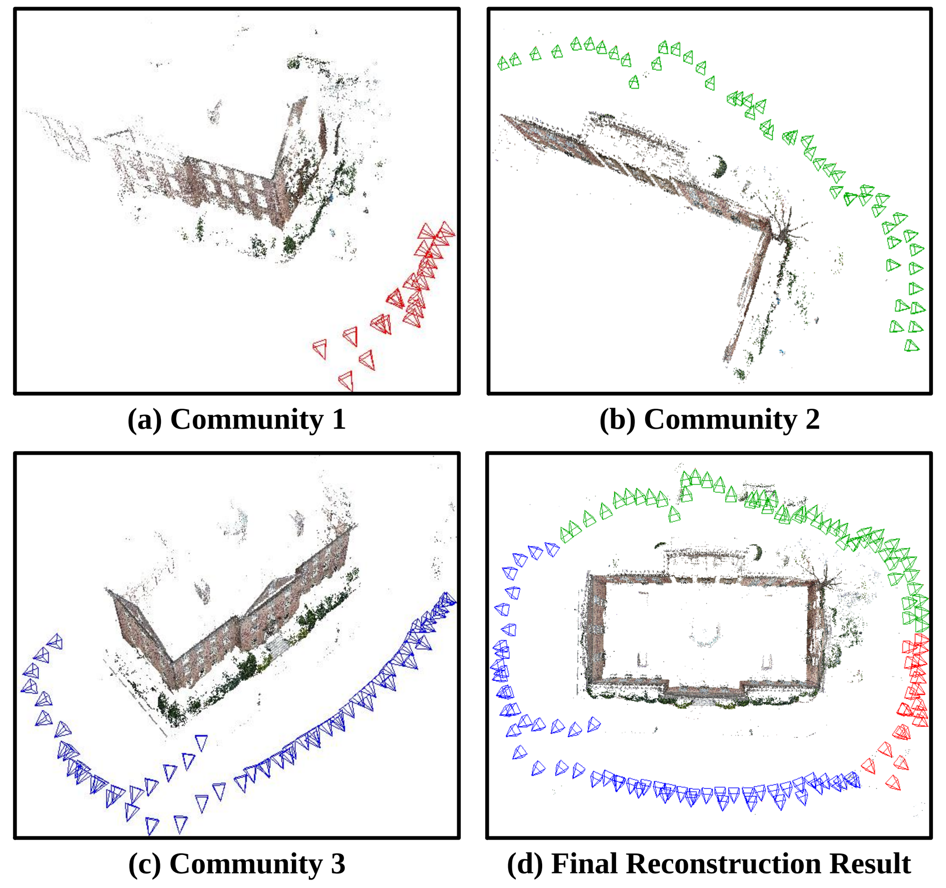
$$\boldsymbol{T}_{ij} = \boldsymbol{T}_j - \boldsymbol{T}_i$$

All these problems are convex L1 problems, and could be solved by [1].

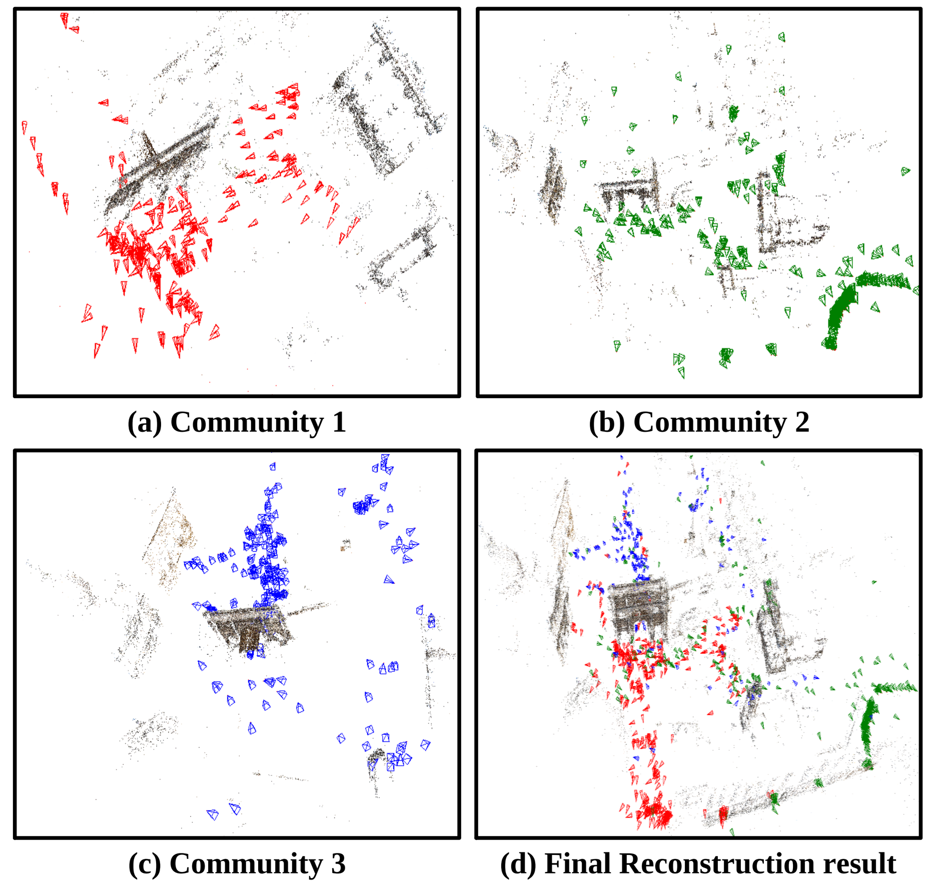
To mitigate the impact of feature match outliers, we perform the final bundle adjustment (BA) after global similarity averaging.

$$\min_{\boldsymbol{K}_i,\boldsymbol{R}_i,\boldsymbol{T}_i,\boldsymbol{X}_j} \sum_{i=1}^{N}\sum_{j=1}^{M} \delta_{ij}\left\|\boldsymbol{x}_{ij} - \gamma(\boldsymbol{K}_i,\boldsymbol{R}_i,\boldsymbol{T}_i,\boldsymbol{X}_j)\right\|_{huber}$$

Illustrative reconstruction process of CSfM system

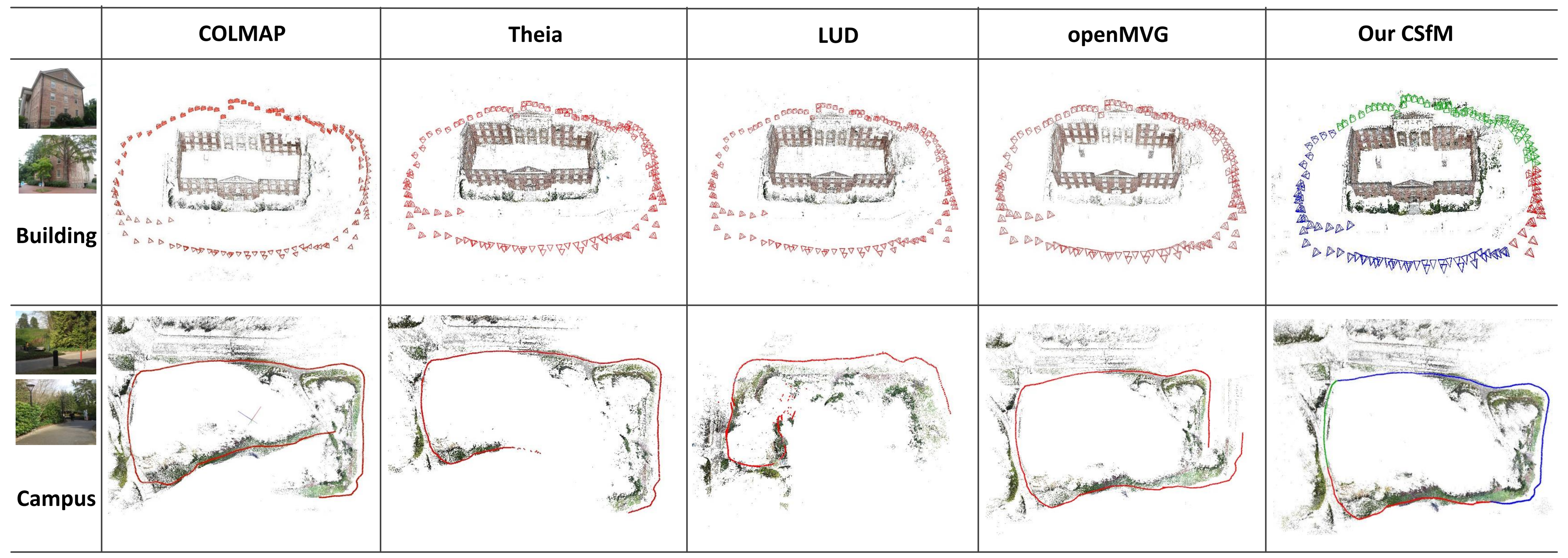


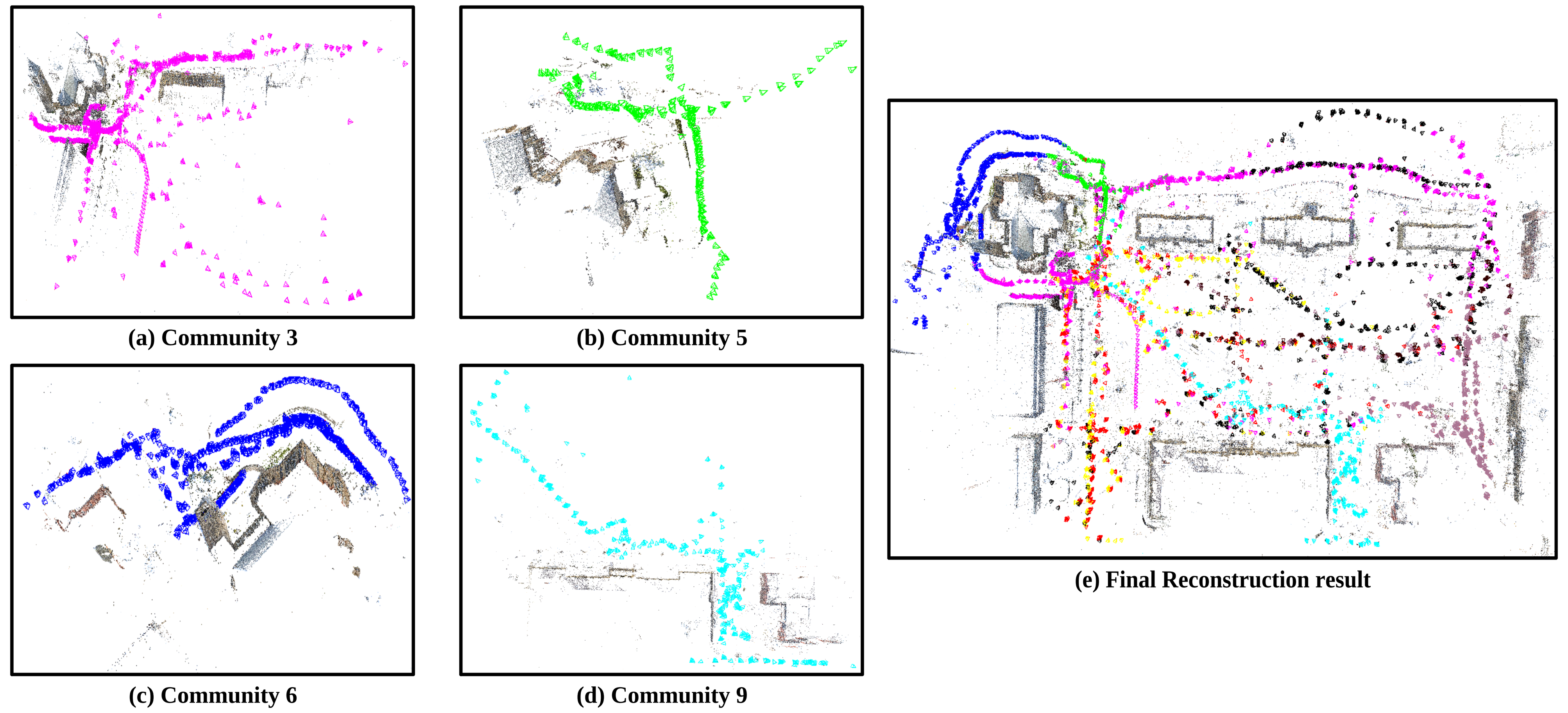
(a) Community 1 (b) Community 2 (c) Community 3 (d) Final Reconstruction Result



(a) Community 1 (b) Community 2 (c) Community 3 (d) Final Reconstruction result

Extensive Experiments





(a) Community 3 (b) Community 5 (c) Community 6 (d) Community 9 (e) Final Reconstruction result

For the dataset Quad [3], with a similar accuracy: DISCO [3] 1.16m, COLMAP [2] 0.85m, Ours 0.83m. The efficiency of our CSfM is 5 times faster than COLMAP [2], and 10 times faster than DISCO [3].

References

[1] Emmanuel Candes, et al. “l1-magic: Recovery of sparse signals via convex pro-gramming” www.acm.caltech.edu/l1magic/downloads/l1magic.pdf, vol. 4, pp. 46, 2005.
[2] Johannes Schonberger, et al. “Structure-from-motion revisited” CVPR2016
[3] D. J. Crandall, et al. “SfM with MRFs: Discrete-continuous optimization for large-scale structure from motion” IEEE TPAMI2013.