Robust Point Cloud Based Reconstruction of Large-Scale Outdoor Scenes

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CVPR LONG BEACH CALIFORNIA June 16-20, 2019

Introduction

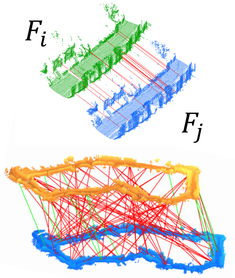
Problem: Outlier feature matches and loop-closures that survived *front-end* data association can lead to catastrophic failures in *back-end* optimization.

Contribution: This work presents a probabilistic approach for robust *back-end* optimization to handle outliers from a weak *front-end* data association.

Reconstruction Pipeline

front-end: Odometry Constraints $X_{i,i+1}$ | Loop-Closure Constraints Y_{ij}

back-end: Robust Reconstruction with EM



Bayesian Network

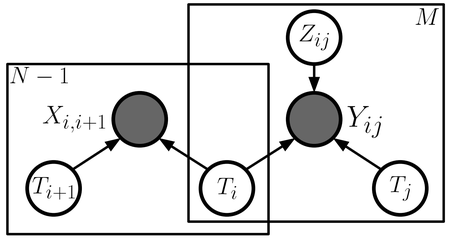
Z: assignment variables

X: odometry constraints

Y: loop-closure constraints

T : fragment poses

sourcecode



Robust Reconstruction with EM

Objective: To find the Maximum a Posterior (MAP) solution

$$\underset{T}{\operatorname{argmax}}\, p(T|X,Y)$$

Solution: **Expectation-Maximization** maximizes the *expected complete data log-likelihood* over the posterior of the latent variable Z. Repeat **E- and M- steps** until convergence.

1. **E-step**: use T^{old}, the fragment poses solved from the previous iteration, to find the posterior distribution of the latent variable Z

$$p(Z|Y,T^{old}) = \frac{p(Y|Z,T^{old})p(Z|T^{old})}{p(Y|T^{old})}$$

2. **M-step**: maximize the expected complete data log-likelihood

$$Q_{EM} := \sum_{Z} p(Z|Y,T^{old}) \ln p(X,Y,Z|T)$$

- **Modeling odometry constraints** $p(X_{i,i+1}|T)$
  feature match $\in X_{i,i+1}$ → Cauchy* distribution
- **Modeling loop-closure constraints** $p(Y_{ij}|T)$
  assignment $p(Z_{ij})$ → Bernoulli distribution
  inlier $p(Y_{ij}|Z_{ij,in}=1,T)$ → Cauchy* distribution
  outlier $p(Y_{ij}|Z_{ij,out}=1,T)$ → uniform distribution
- ***Generalization**
  Assume no outlier feature matches, Cauchy distribution can be replaced with Gaussian, which leads to a state-of- the-art approach for robust indoor reconstruction [1].

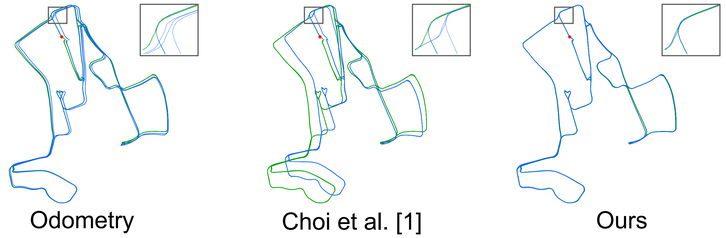
Results

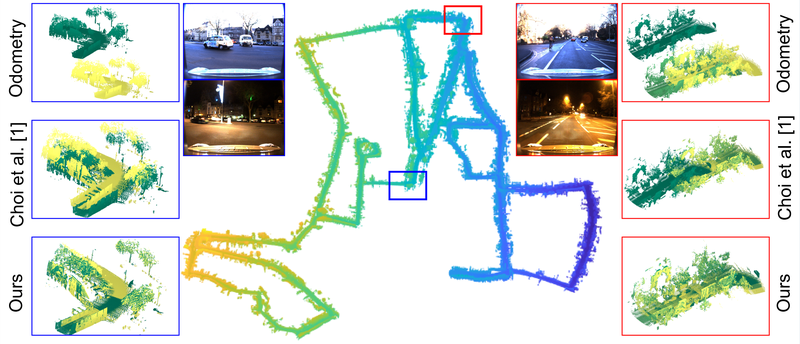
Small-scale indoor scenes

Trajectory	Living Room 1	Living Room 2	Office 1	Office 2	average
Choi et al. [1]	0.04	0.07	0.03	0.04	0.05
Ours (Gaussian)	0.06	0.09	0.05	0.04	0.06
Ground Truth	0.04	0.04	0.03	0.03	0.04

Reconstruction accuracy. Numbers are mean distances to the ground truth surfaces (in meters). Ours is on-par with the state-of-the-art [1].

Large-scale outdoor scenes





[1] S. Choi, Q.-Y. Zhou, and V. Koltun. Robust reconstruction of indoor scenes. In CVPR, 2015.