Combining image and LiDAR draws increasing interest in surface reconstruction, city and building modeling for constructing 3D virtual reality models because of their complementary nature. However, to gain from this complementarity, these data sources must be precisely registered.

The basic idea of the proposed algorithm consists in defining a global robust distance between two segment sets and proposing a robust approach to minimize this distance based on RANSAC paradigm.

Feature Extraction

3D line segments detection from an indoor scan

3D line cloud reconstruction from image sequence

Pipeline details

3D segments → Feature Extraction → Clustering → Cluster Association → RANSAC: Possible 3D segment correspondences → Robust Global Distance → Optimization → Best Transformation → Least Squares → Final Transformation → Global Robust distance between segment sets

3D segments based algorithm for heterogeneous data registration

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Context and Objectives of the Study

- Combining image and LiDAR draws increasing interest in surface reconstruction, city and building modeling for constructing 3D virtual reality models because of their complementary nature. However, to gain from this complementarity, these data sources must be precisely registered.
- The objective of this study is to propose a new primitive based registration algorithm that takes 3D segments as features in order to register heterogeneous data. The heterogeneity is both in data type (image and LiDAR) and acquisition platform (terrestrial and aerial).
- The basic idea of the proposed algorithm consists in defining a global robust distance between two segment sets and proposing a robust approach to minimize this distance based on RANSAC paradigm.

Evaluation on synthetic data

Comparison of the convergence speed and the robustness of RANSAC and simulated annealing

Performance tests of our algorithm on synthetic data using different initial errors.

Evaluation on Real data

Terrestrial image/Terrestrial LiDAR registration

Aerial image/Terrestrial image registration

Feature Extraction

Algorithm 1: Greedy direction clustering

1. Input: set of segment L, each segment \( L_i = \{A_i, B_i\} \)
   has a director vector \( v_i = \overrightarrow{A_iB_i} \), a length \( len_i = ||v_i|| \) and a unit direction \( d_i = \frac{v_i}{len_i} \).

2. Initialize an empty set of 3D segment Clusters \( C \).

3. For each segment \( L_i \):
   - If \( C \neq \emptyset \) or \( max_{c \in C} d_i < \cos(\varepsilon) \), create a new cluster and add \( L_i \) to it.
   - Else add \( L_i \) to the cluster \( arg \ max \ d_i, d(c) \)

Valid cluster associations

We have two segment sets \( S_1 \) and \( S_2 \)

For each cluster associations

\[ A_s = \{c_1^1, c_2^1 \} \in S_1 \rightarrow \{c_1^2, c_2^2 \} \in S_2 \]

we have several possible forms.

As for each cluster \( c \), we have two possible direction vectors: \( (d(c), -d(c)) \); we can define the variables \( s_{ij}^k \); \( i \in \{1, 2\}, j \in \{1, 2\}, s_{ij}^k = \pm 1 \)

If one of the possible forms of \( A_s \) satisfies the condition:

\[ |s_{ij}^k d(c_1^i), s_{ij}^k d(c_2^i) > - |s_{ij}^k d(c_1^j), s_{ij}^k d(c_2^j) | < \varepsilon \]

we consider that \( A_s \) is valid

Else, we reject this association

Optimization

Simulated annealing simulation:

- A new solution is iteratively computed in the vicinity of the current solution.
- This new solution is accepted with certain probability depending of its energy (the robust distance in our case).

RANSAC optimization

- At each RANSAC iteration, we randomly select a valid cluster association, then randomly select 3D segment in each of the associated clusters.
- We compute the rotation based on cluster association.
- We estimate the scale/translation that aligns the associated 3D segments.

Future Works

- Use planar polygons as primitives.
- Use combinations of more segments to have more characteristic features to match.
- Test the proposed algorithm for solving the aerial image/Aerial LiDAR registration.

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