Correspondence Rejection by Trilateration for 3D Point Cloud Registration

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Introduction

A common need in computer vision and pattern recognition is to compute the 3D rigid body transformations that align two or more point clouds. The process of placing two or more 3D data sets or point clouds in the same coordinate system is a crucial step for the accurate reconstruction of 3D models for a variety of applications such as architecture, gaming, medical imaging, heritage conservation, robotics and industrial automation. Robust descriptor and correspondence estimation algorithms are able to identify corresponding pairs of points from objects captured from different positions and orientations; consequently, this also means that locally indistinguishable but spurious correspondences are likely to be identified.

The final steps of the registration process can be greatly and negatively impacted by spurious correspondences, and so rely heavily on robust correspondence rejection algorithms.

Trilateration is typically used to solve localisation problems for positioning systems, navigation and tracking, but here we extend this for the application of correspondence rejection.

Faro Focus3D Scanner

Registration

Registration generally consists of the following steps:

1. Feature Extraction/Detection
2. Feature Description
3. Correspondence Estimation
4. Correspondence Rejection
5. Coarse Registration
6. Fine Registration

Aim

To determine the effectiveness of trilateration as a means of robust correspondence rejection in heavily contaminated correspondence sets.

Trilateration is used here to estimate the position of the origin of one scan relative to another. Correspondences which correctly estimate the position are considered members of the inlier subset.

Trilateration

Trilateration is the process of determining the position of a point by distance measurements using the geometry of spheres for 3D or circles for 2D.

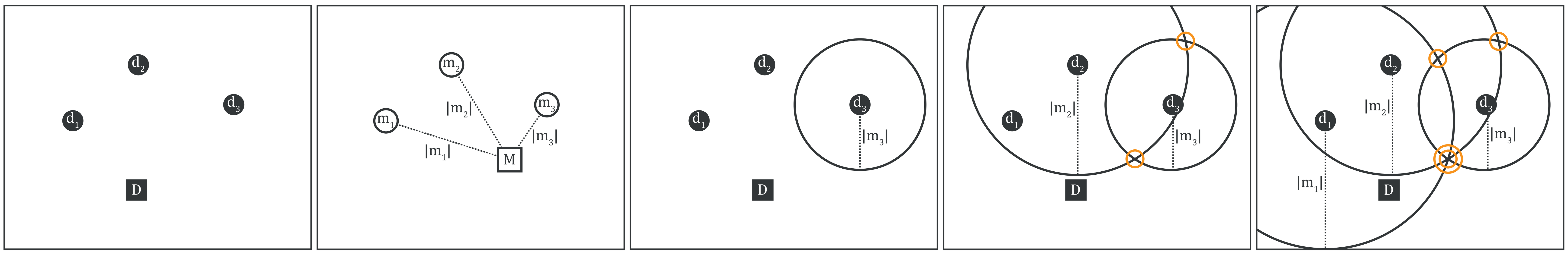
If it is known that a point lies on the surface of 4 different spheres, the centres and the radii provide sufficient information to determine the location.

Solving trilateration for any combination of 4 true correspondences will correctly estimate the position of the scan in question.

Trilateration solutions for all true 4-combination subsets will produce a very dense cluster of points which can be isolated from the other points.

By determining the frequency of corresponding points contributing to this dense cluster, spurious correspondences may be completely separable from the true correspondences.

Trilateration: A 2D Example



A scene is scanned from position D and three features are extracted (d_1, d_2, d_3).

The same scene is scanned from position M. Three corresponding features are identified (m_1, m_2, m_3) and their distances from the scanner are evaluated ($|m_1|$, $|m_2|$, $|m_3|$).

A circle for point d_3 of corresponding radius $|m_3|$ is constructed.

A circle for point d_2 of corresponding radius $|m_2|$ is then constructed and two intersections are observed (circled), one of which corresponds to the position of M.

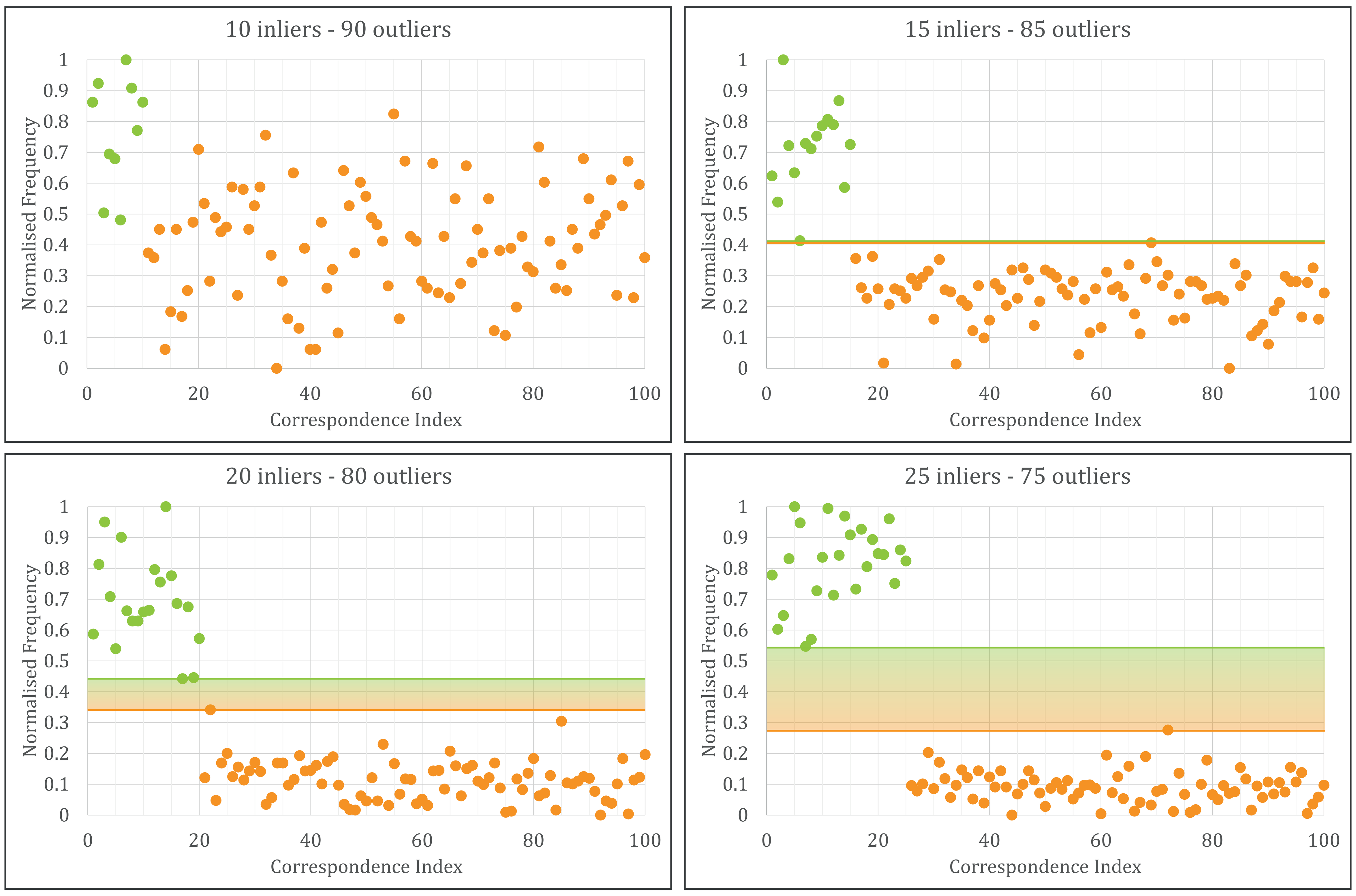
The third and final circle for point d_1 of corresponding radius $|m_1|$ is then constructed and additional intersections are observed. The multiple intersections indicated by the double ring estimate the position of M.

Method

1. Generate two random 3D point clouds confined within a 10m radius sphere with 100 points each.
2. Each point in both point clouds will have an assumed correspondence defined by alike indices.
3. The first n correspondences are true while the rest are spurious.
4. Each point is perturbed by a random variable $X \sim N_3(0, 0.0025\text{m})$.
5. Evaluate the trilateration set and retain solutions which are within 0.0025m of all relevant sphere radii.
6. Plot the frequency of each correspondence in the reduced trilateration set.
7. True correspondences may be resolved using an appropriate clustering algorithm.

Results

Scatter graphs showing the normalised frequency of correspondence points found in the reduced trilateration set. Inliers Outliers



Analysis

- All test cases on the left are heavily contaminated with inliers contributing to only 10-25% of the correspondence set.
- Most or all of the true correspondences may be retrieved for n>15.
- For the cases of n=15, 20 and 25, two clusters containing most or all true correspondences are easily distinguishable.
- For n=10 it is difficult to distinguish and reliably separate the inliers from the outliers.

Conclusion

- Trilateration for correspondence rejection is shown to be very robust to heavy contamination.
- The noise simulated here is similar to that of a typical LIDAR scanner. The algorithm is able to retrieve true correspondences from heavily contaminated sets for this level of noise.
- Large correspondence sets may lead to excessive computation time if all subsets require evaluation.
- The final result of true correspondences will ultimately be dependent on the choice of clustering algorithm.
- Further testing and analysis is required to better understand the capability of the algorithm and its limitations.
- Comparison with other correspondence rejection algorithms such as RANSAC is required.
- Further testing with real LIDAR data is required.

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