ICCV 2025

Correspondence-Free Fast and Robust Spherical Point Pattern Registration

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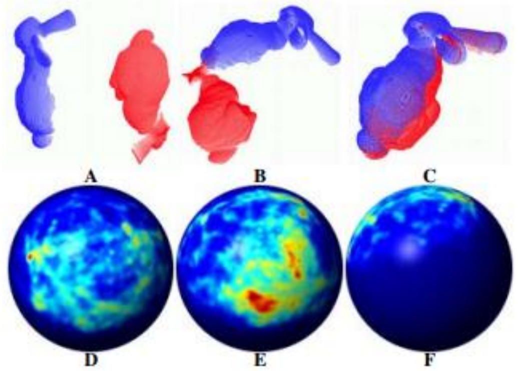
Background & Motivation

Many signals are inherently spherical
(omnidirectional images, earth maps etc.)

In the past, spherical pattern matching was used for:

- Point cloud registration (global alignment on SO(3))
- Spherical image registration (rotation estimation)

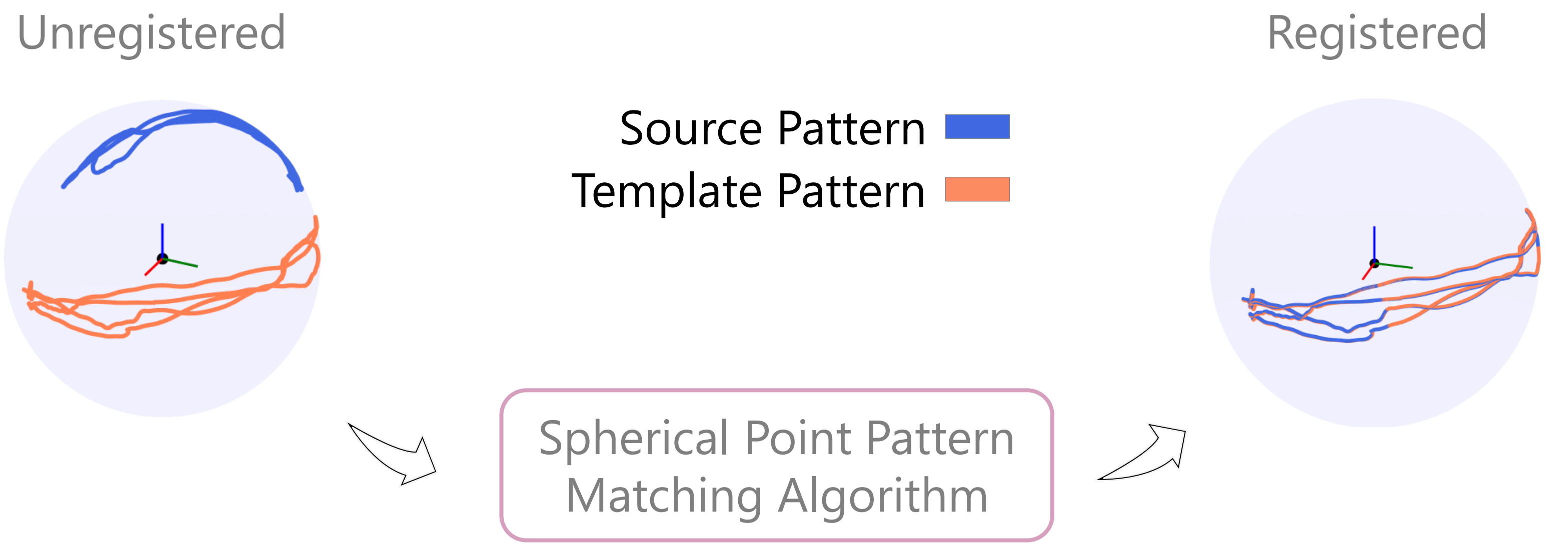


[Makadia et.al]

Background & Motivation

In spherical cross-correlation, spherical patterns are treated as functions

We treat spherical pattern matching as point pattern registration on the surface of a unit sphere

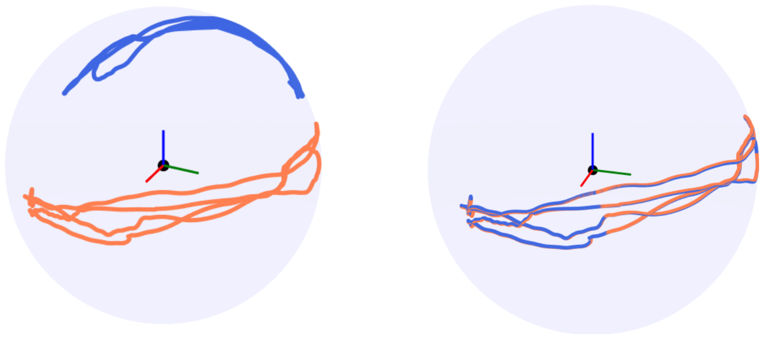


Background & Motivation

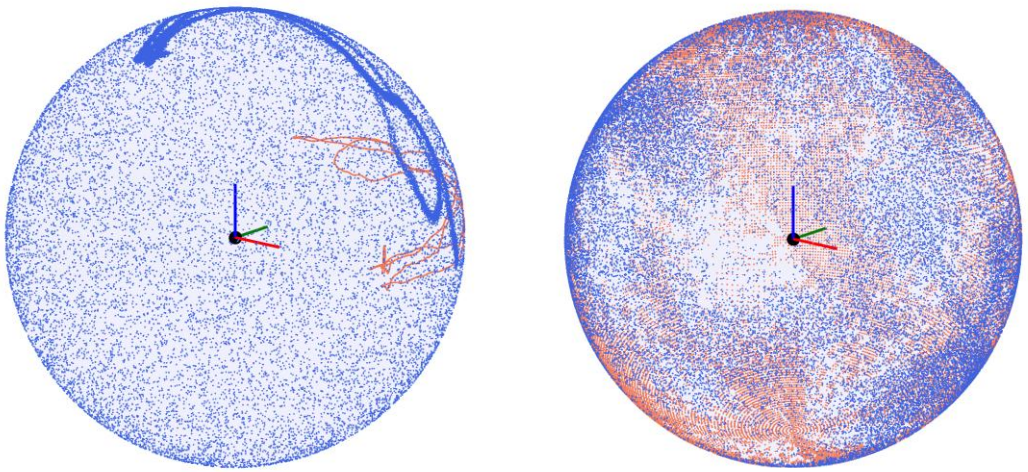
One to One Correspondence (easy)

[closed form solution exists]

Unregistered Registered



The problem becomes challenging under large rotations, heavy noise/outliers, or complex patterns.

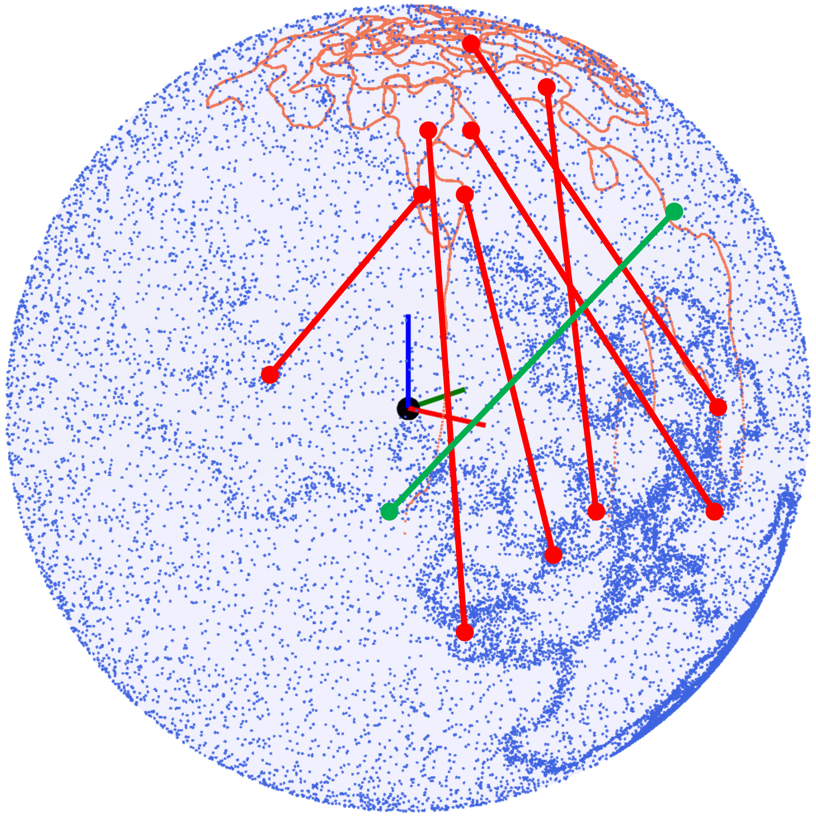


Background & Motivation

Corresponded based Methods

Finding reliable correspondences in spherical patterns with noise and outliers is extremely challenging. Due to

- lack of geometric variation
- overlapping regions, and inherent symmetries



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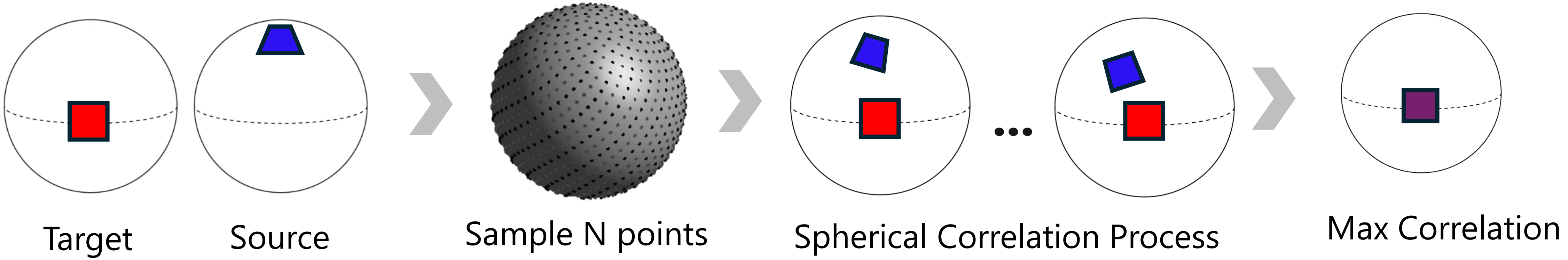
Background & Motivation

Spherical Correlation Based Methods



Spherical cross-correlation is expensive; runtime grows rapidly with the rotational sampling, spherical harmonic bandlimit.

Methods
(Overview)

We developed 3 Algorithms

Algorithm 1: SPMC (Spherical Pattern Matching by Correlation)

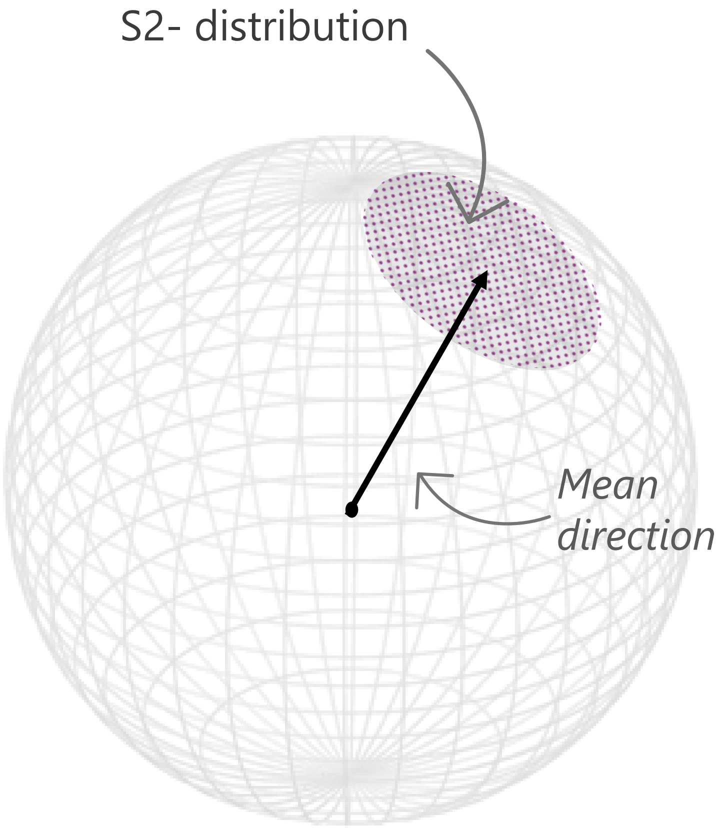
Algorithm 2: FRS (Fast Rotation Search)

Algorithm 3: SPMC + FRS (combines the first two)

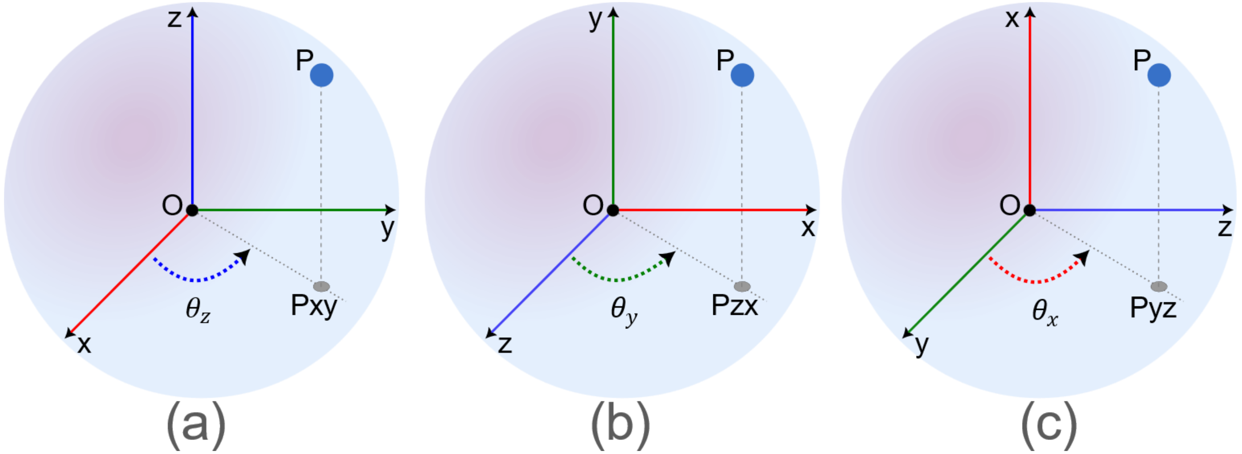
Methods

(Terminologies)

Mean Direction of Spherical Pattern



Axis Direction Angles of an S2 Point



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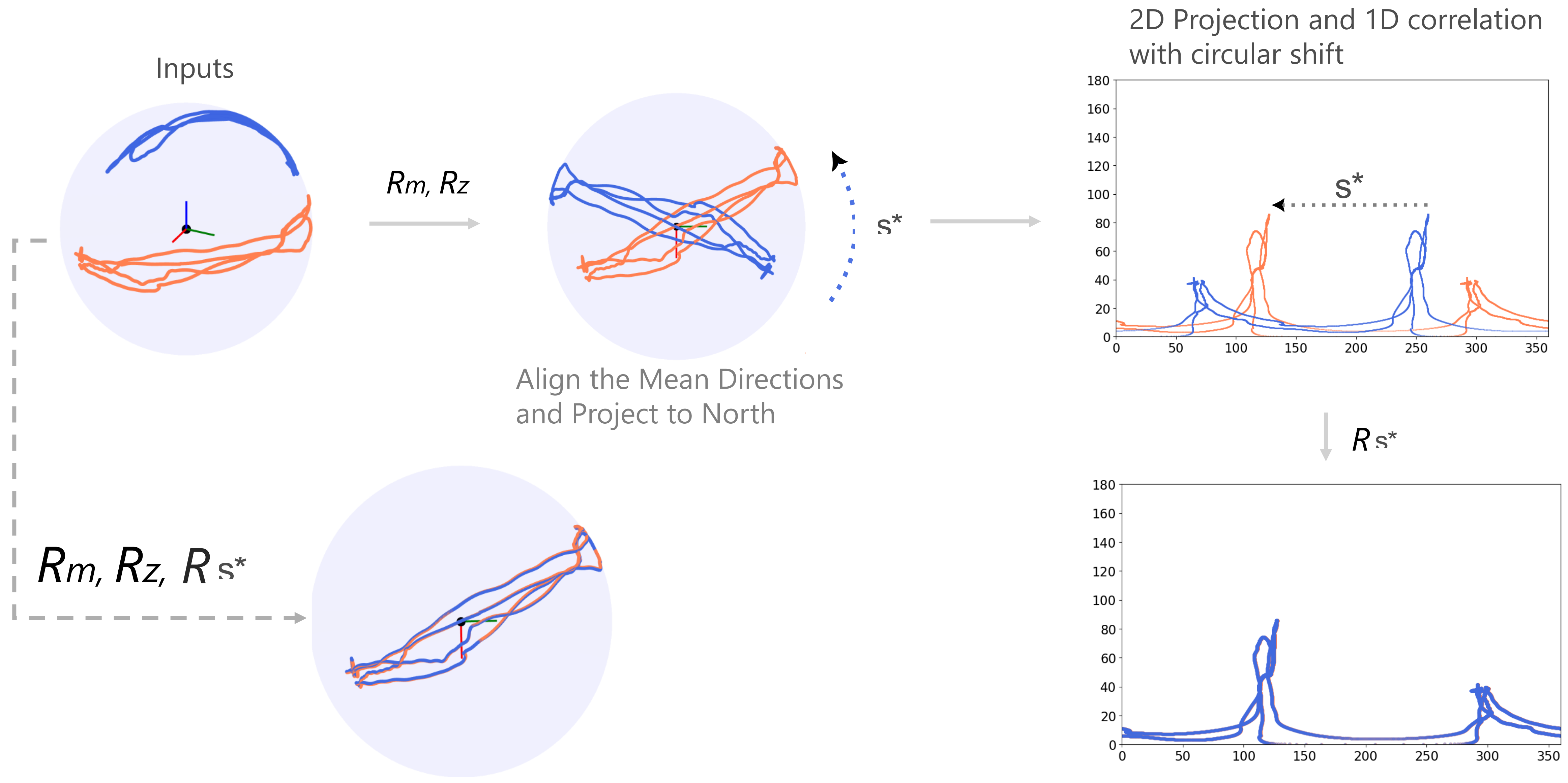
Methods

Algorithm 1: SPMC

Template Pattern:

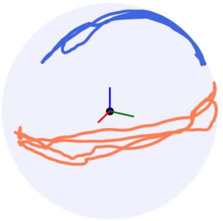
Source Pattern:



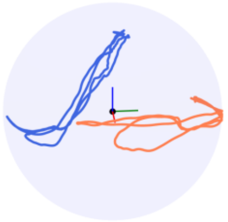
Methods Algorithm 2: FRS

Template Pattern:
Source Pattern:

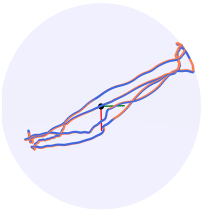
Inputs



$R_{x(i)}$ $R_{y(i)}$ $R_{z(i)}$

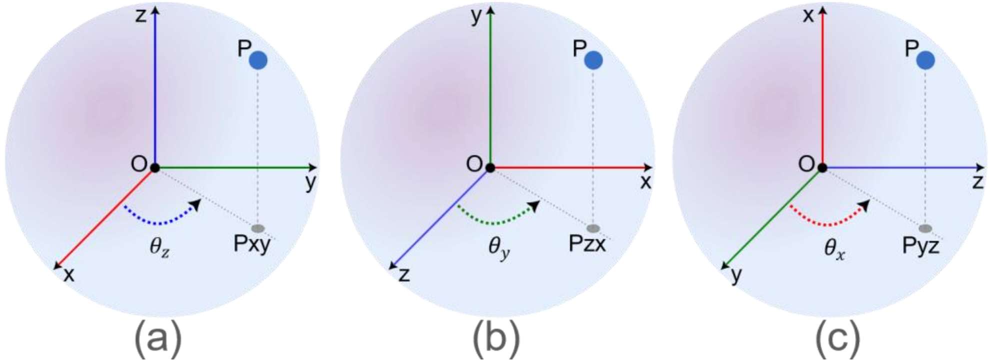


Iterate until converges

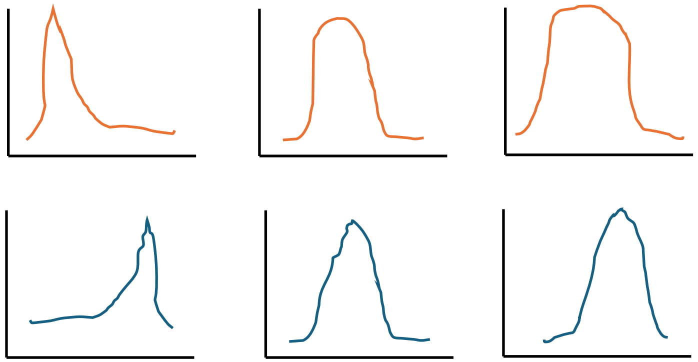


Iteration (i)

Axis Direction Angles

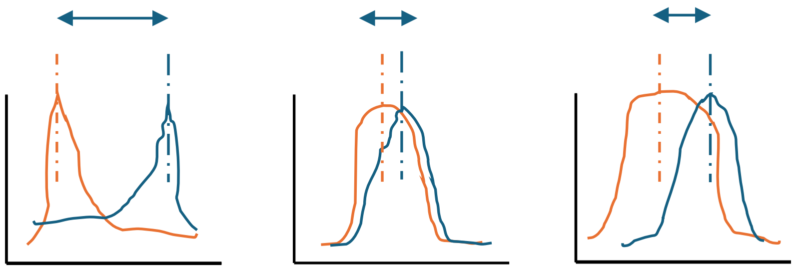


x-hist y-hist z-hist



Horizontal Bins (360)
Vertical Bins (180)

$R_{x(i)}$ $R_{y(i)}$ $R_{z(i)}$



Methods

Algorithm 3: SPMC+ FRS

Algorithm 1: SPMC

- Mean direction is sensitive to when noise and outliers are significant

Algorithm 2: FRS

- Sensitive to initialization

Algorithm 3: SPMC +FRS

- SPMC provides a good initialization. FRS converges even faster

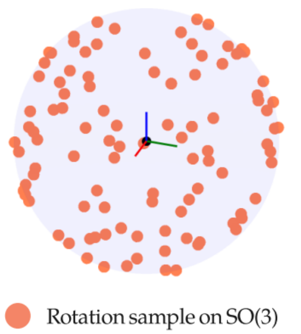
Novel Synthetic Dataset

Robust Vector Alignment Dataset

5 Random patterns (A1,..., A5)

7 Levels of Noise and Outliers (B1,..,B7)

100 Random Rotation



A5B1: noise σ=0.0, outliers 0%

A5B2: noise σ=0.01, outliers 10%

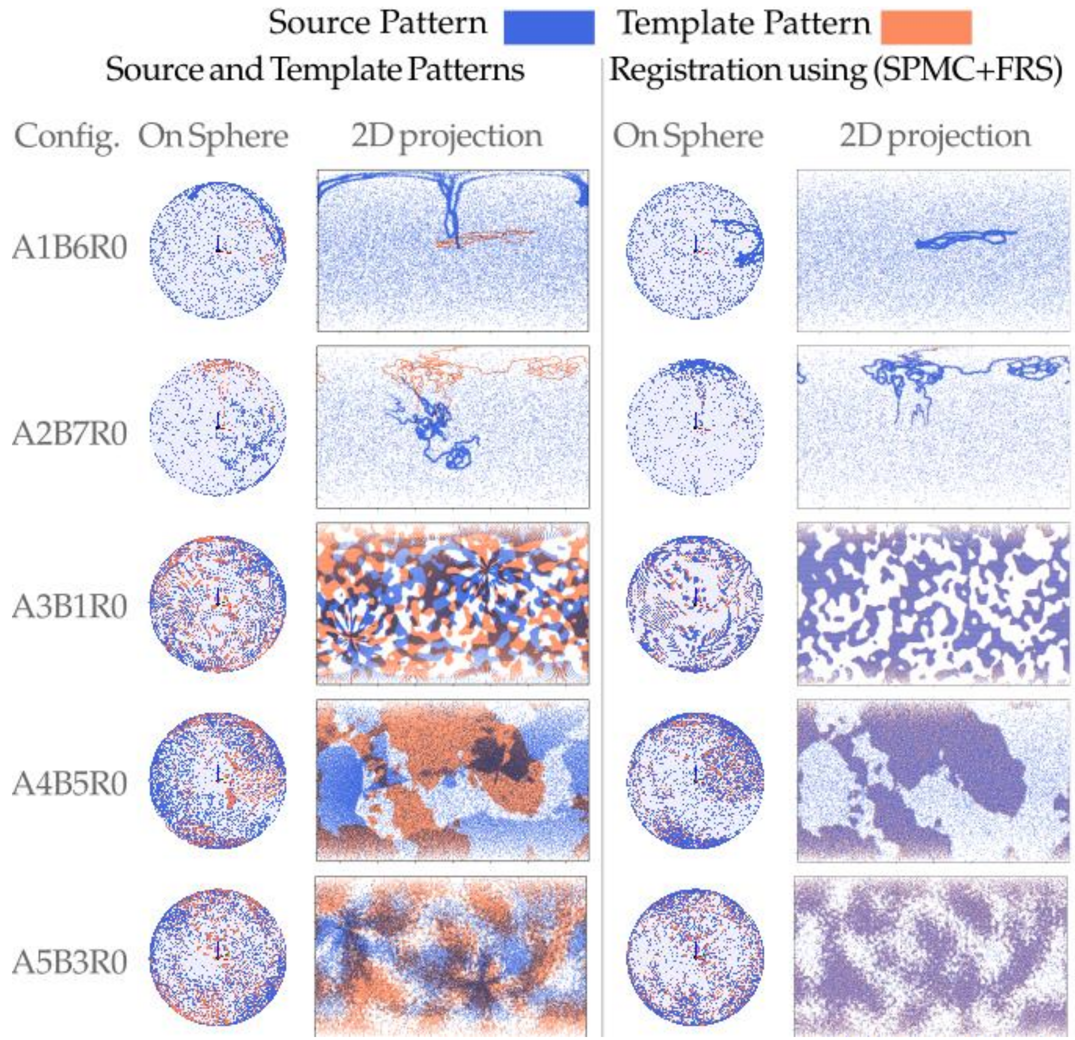
A5B3: noise σ=0.01, outliers 50%

A5B4: noise σ=0.01, outliers 90%

A5B5: noise σ=0.1, outliers 10%

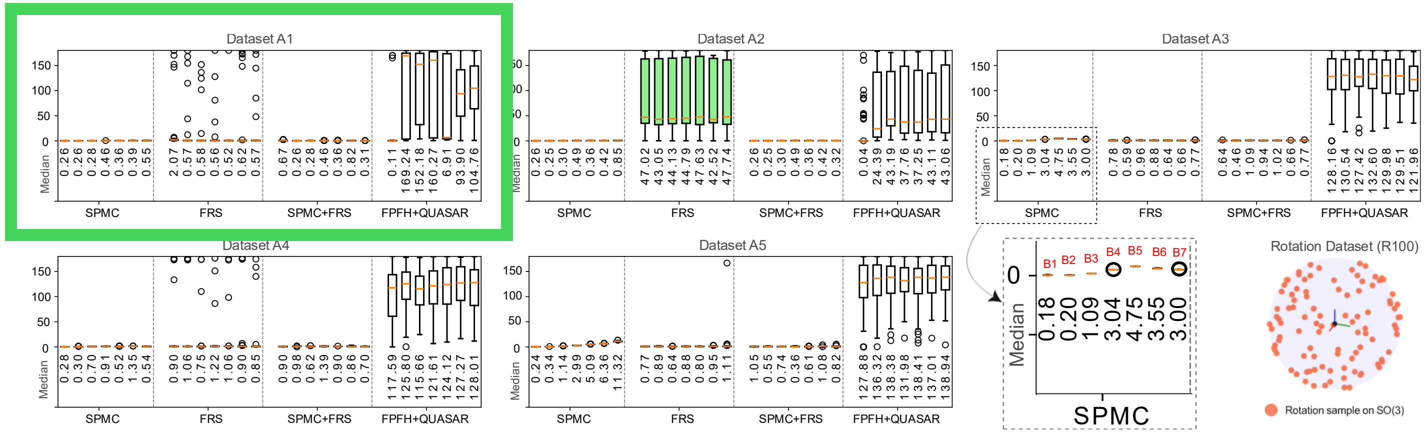
A5B6: noise σ=0.1, outliers 50%

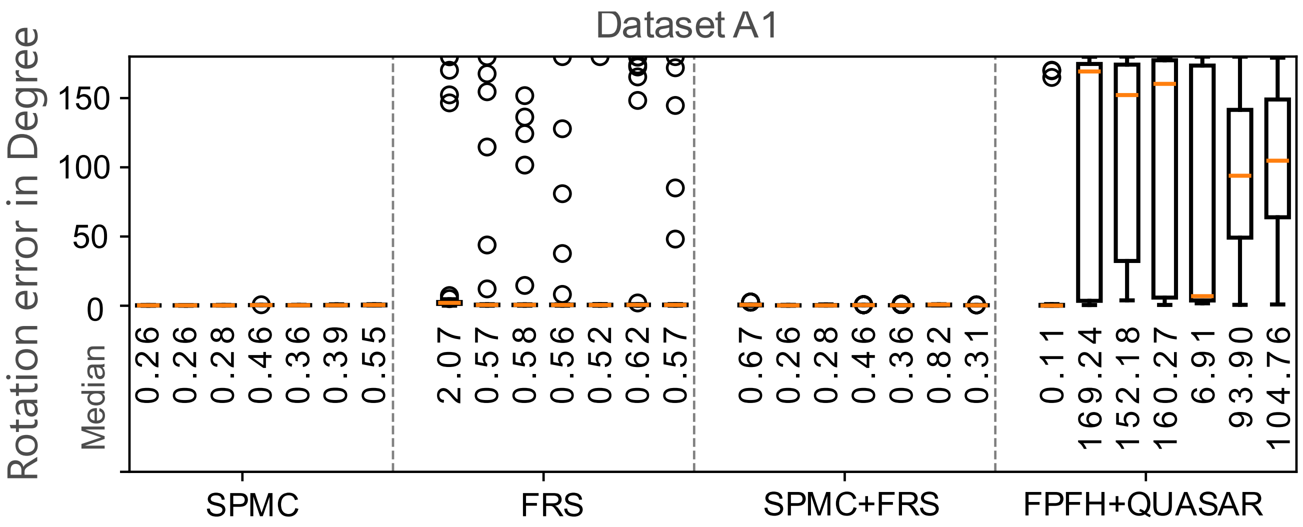
A5B7: noise σ=0.1, outliers 90%

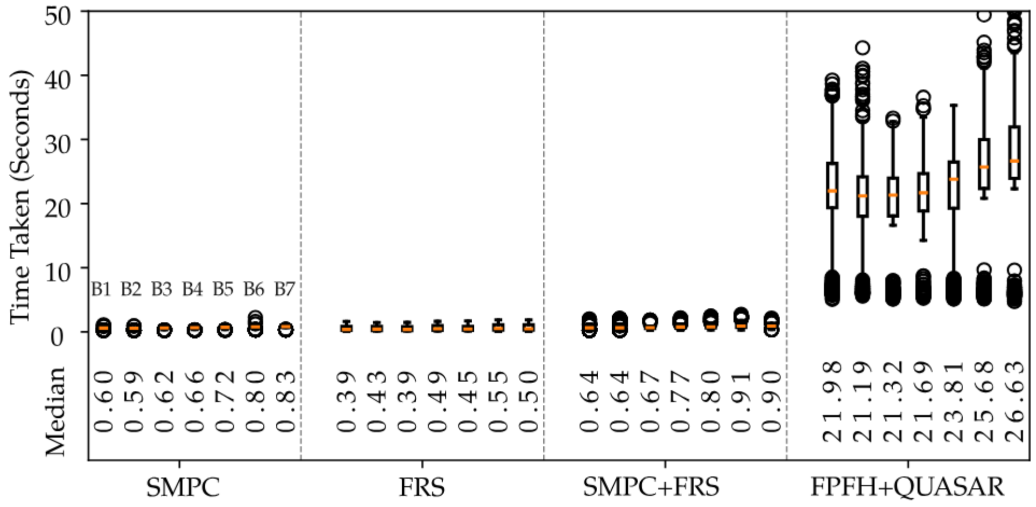


Results

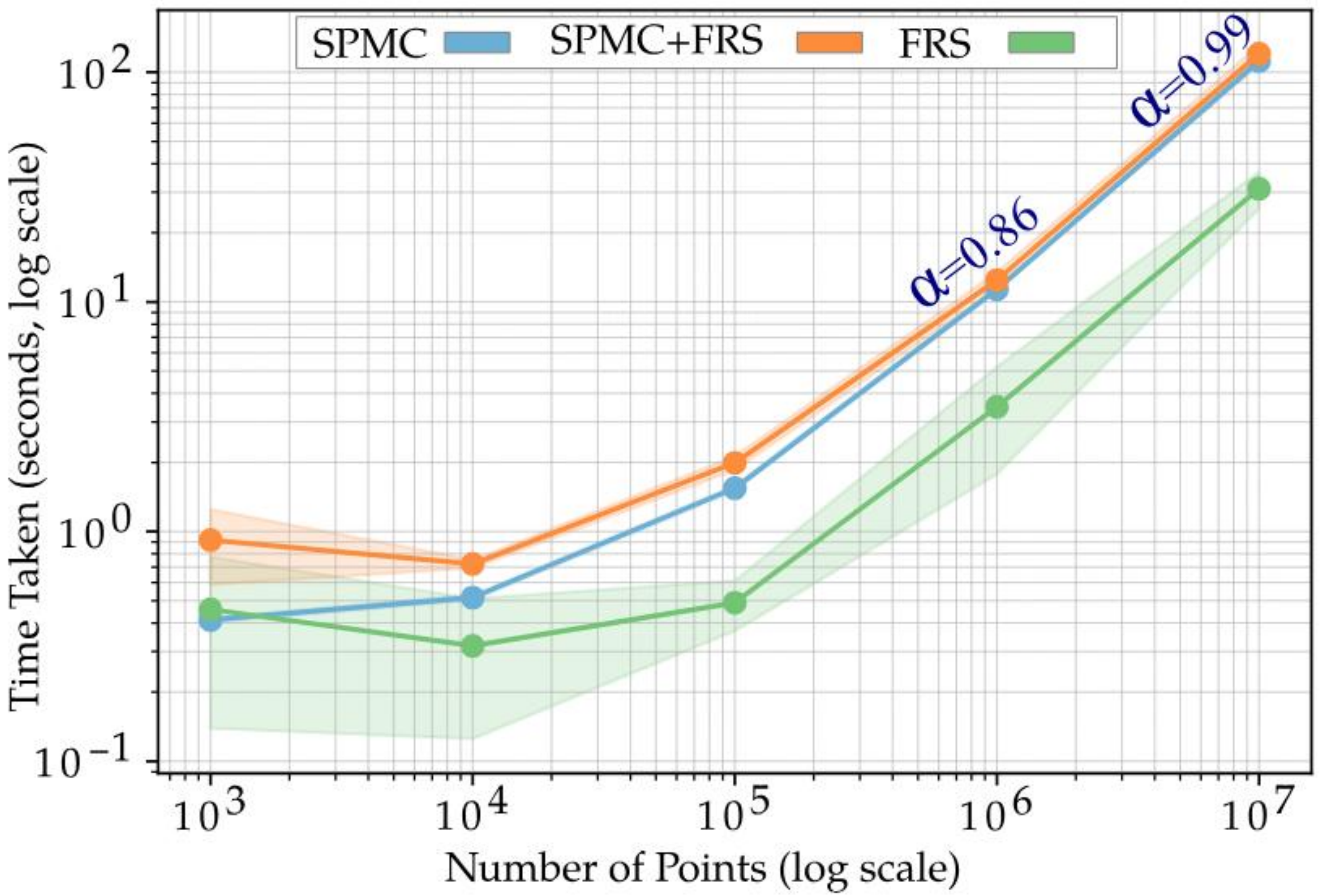
Robust Vector Alignment Dataset







Time Complexity: ~O(N)



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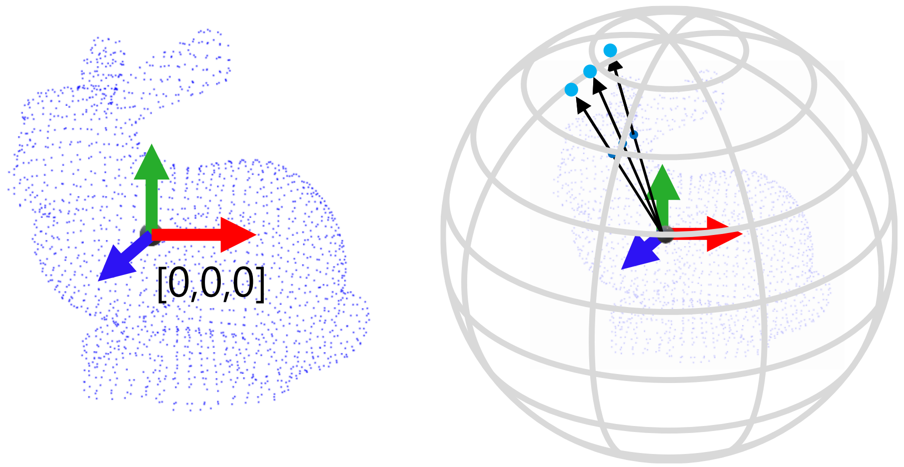
Application 1: Point Cloud Registration

Rotational alignment (our method)
Translation estimation [adaptive voting (e.g TEASER) or centroid shift (for complete to complete)]

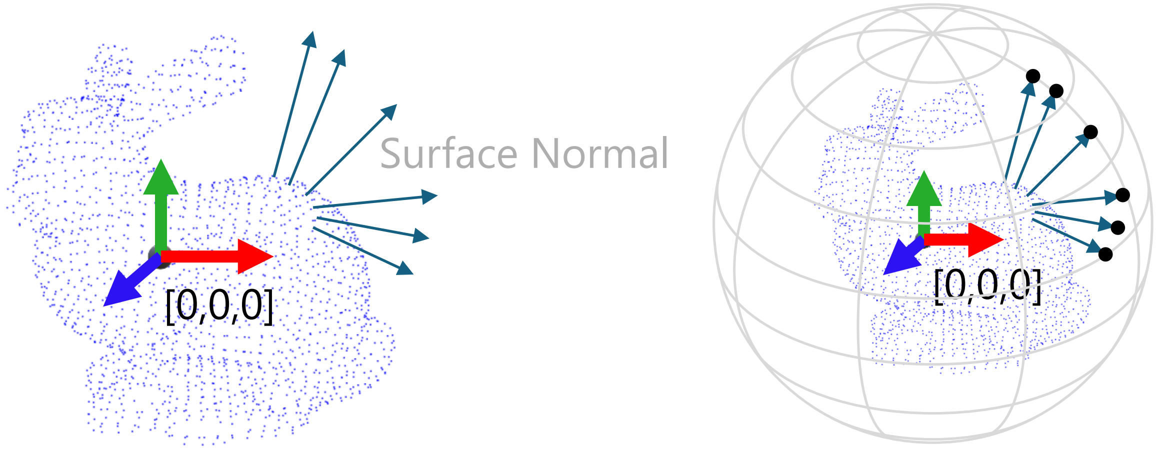
Spherical Representation of Point Cloud

1) CASE (Centroid Aware Spherical Embedding)



Applicable if we know the complete geometry of the objects (complete to complete registration)

2) EGI (Extended Gaussian Image)



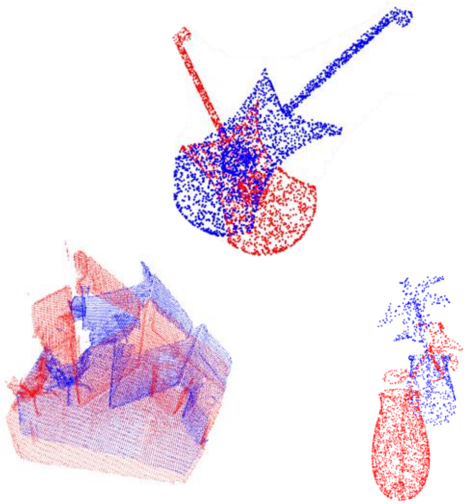
Can generate spherical signal for partial point cloud

Application 1: Point Cloud Registration

Point Clouds

Spherical Embedding

After Registration



CASE

(Centroid Aware Spherical Embedding)

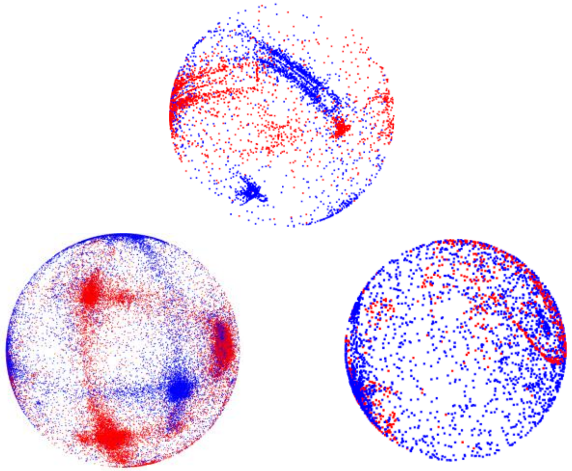
Complete to Complete

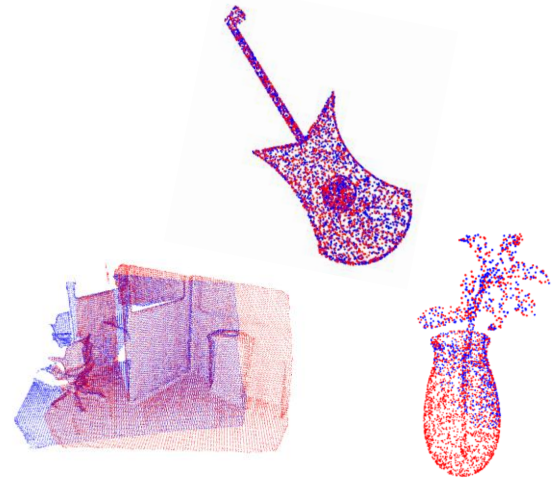
EGI

(Extended Gaussian Image)

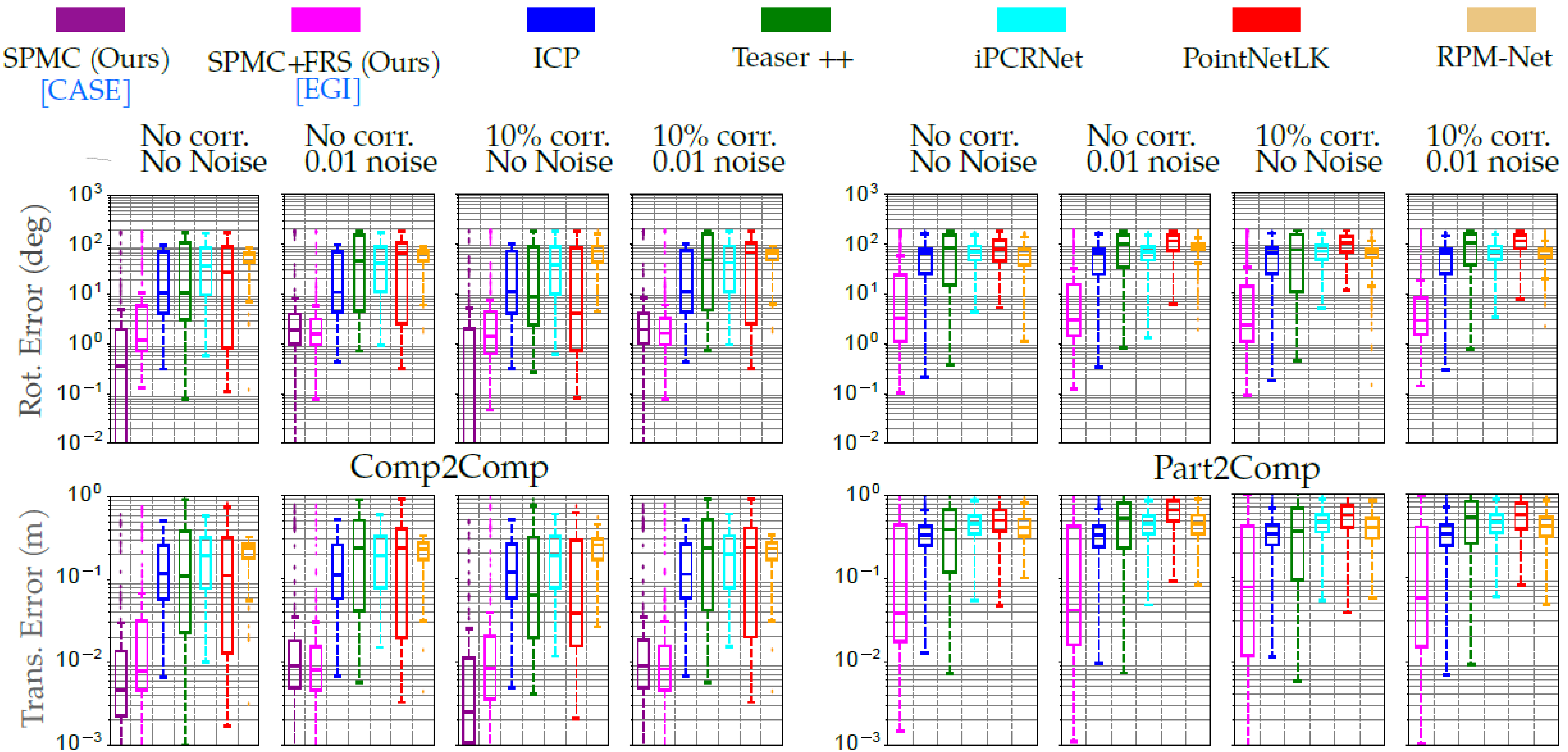
Partial to Partial,

Partial to Complete

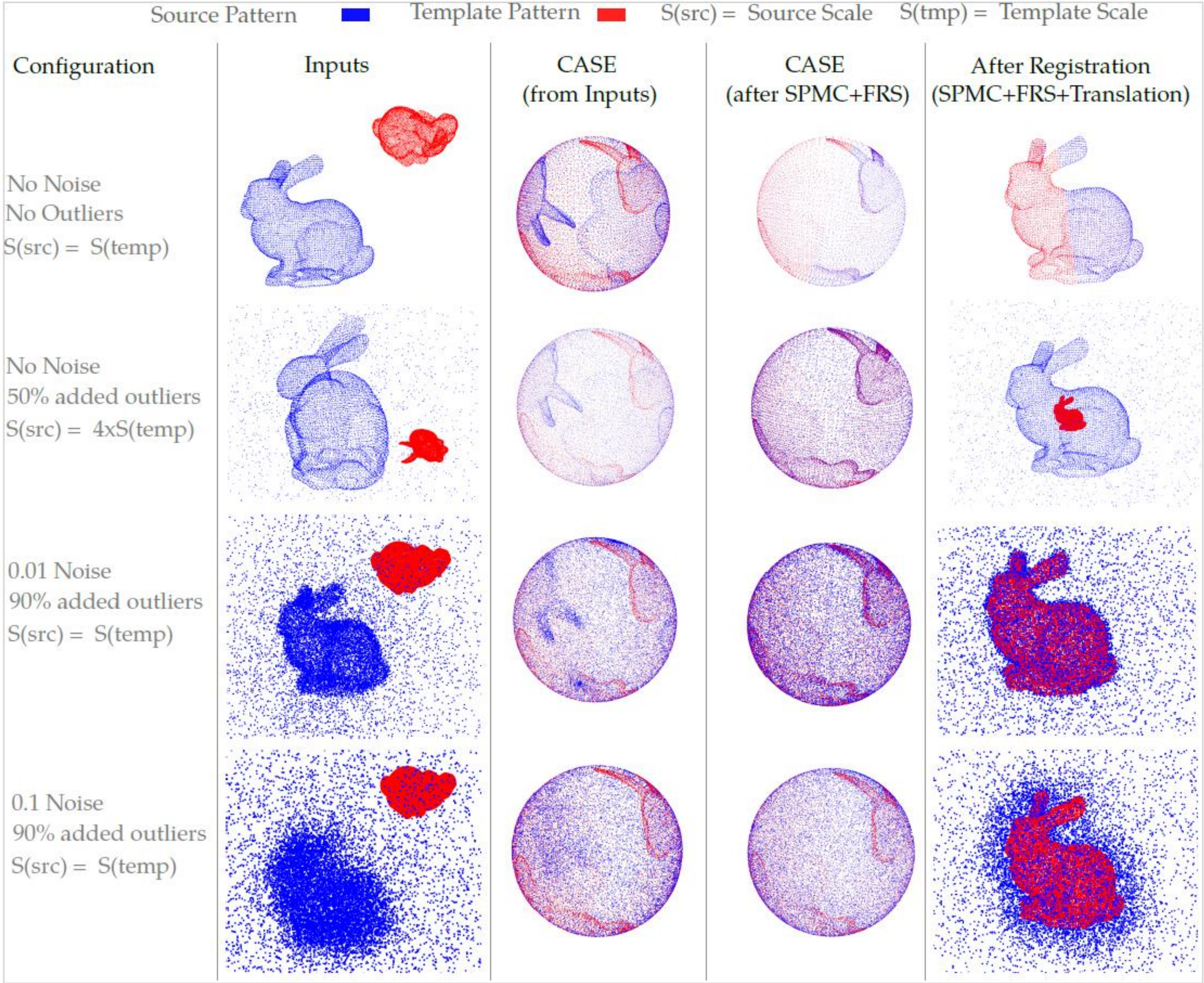




Quantitative Evaluation: ModelNet40



Qualitative Evaluation: Bunny Dataset (complete to complete)



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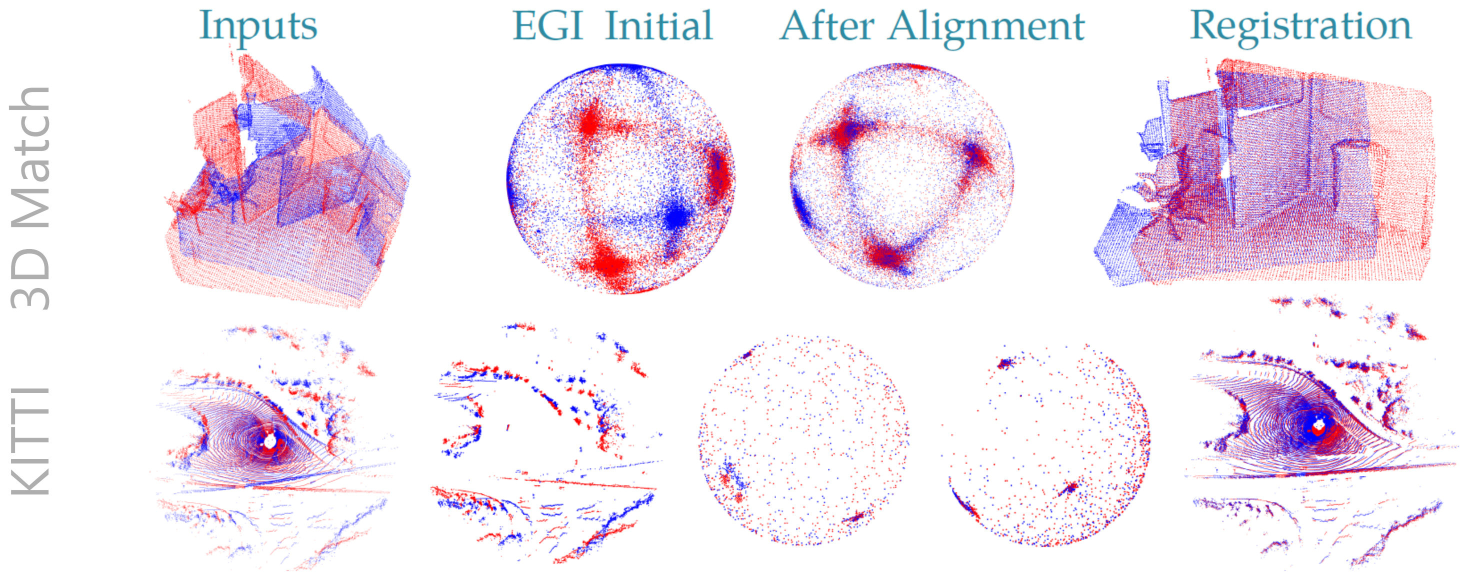
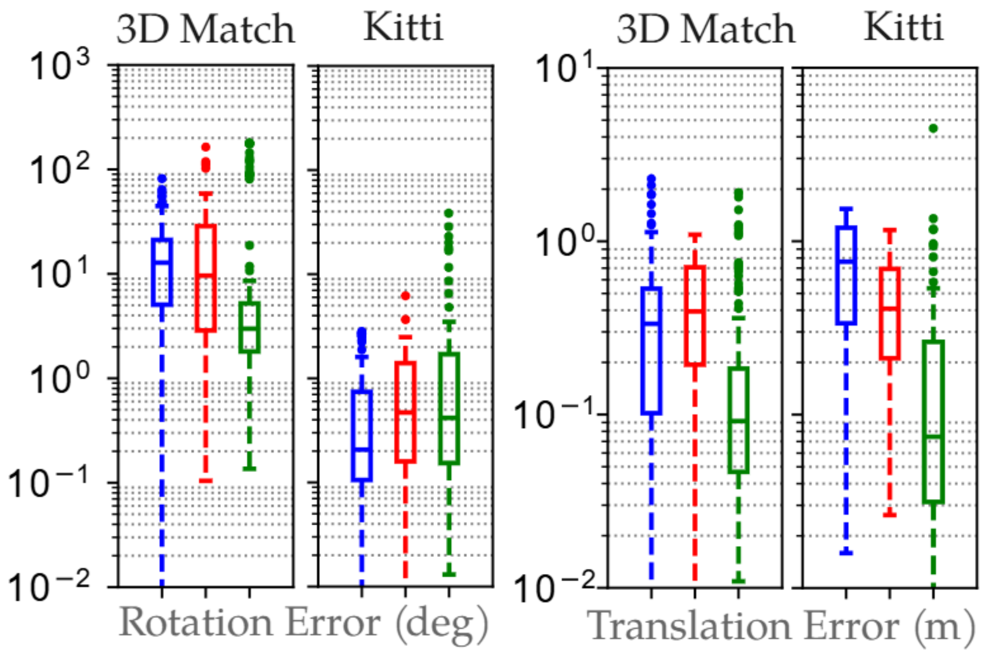
Quantitative Evaluation:
KITTI, 3D Match





RANSAC 1K
TEASER++
Ours

Avg. Sample Run-Time

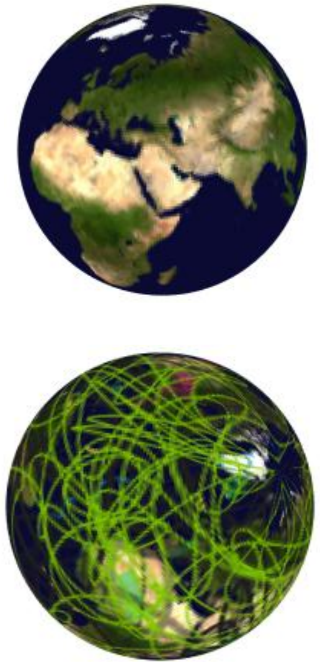
3D Match	
RANSAC 1K	1.24 s
TEASER++	2.86s
Ours	0.93 s
Kitti	
RANSAC 1K	0.85 s
TEASER++	1.39s
Ours	0.71 s

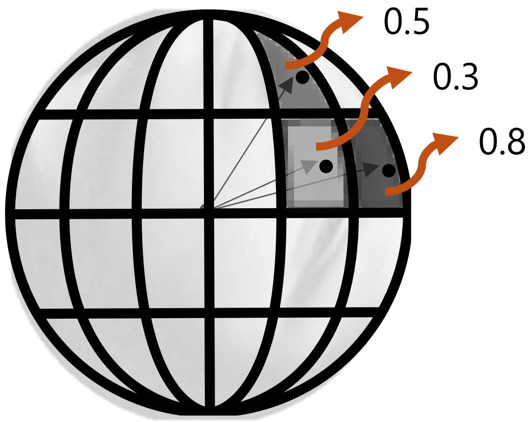
Application 2: Spherical Image Registration

Point Cloud Represnation of Spherical Image

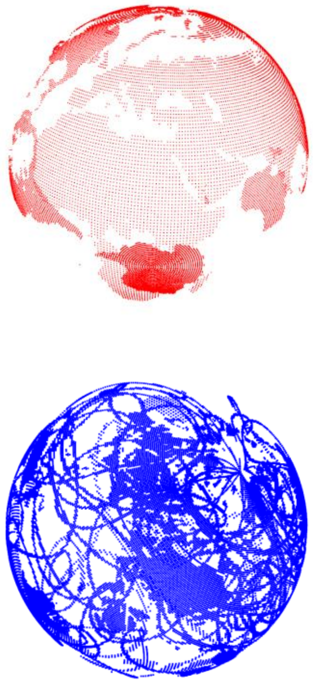
Target Spherical Image

Source Spherical Image (Rotated + Cluttered)

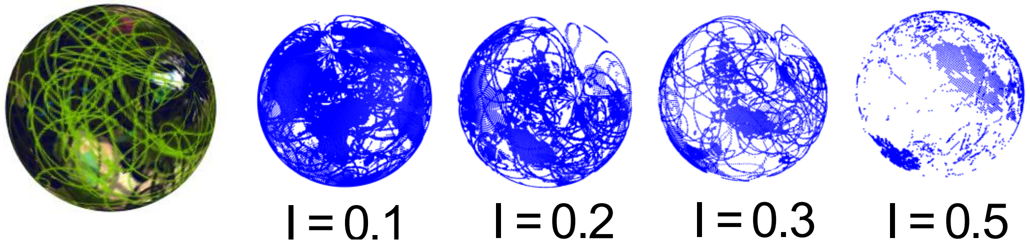




SphImg2SphPoints



Effect of different thresholding value



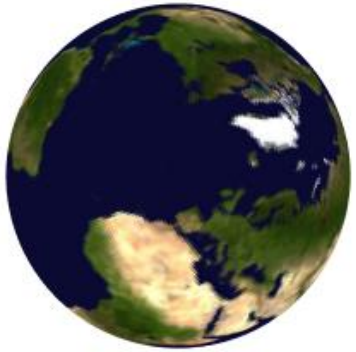
Qualitative Evaluation: Map data

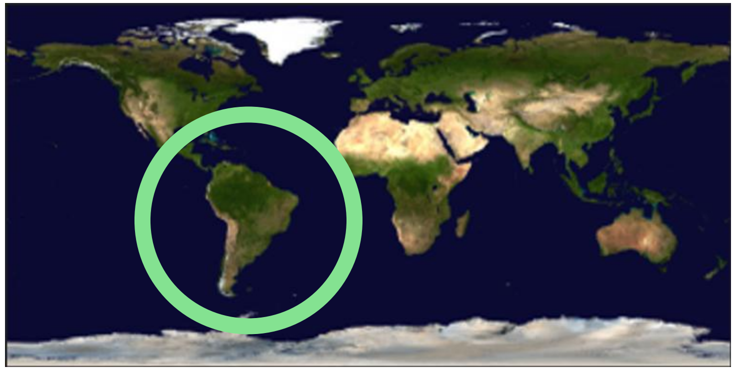
Template Spherical Image & 2D Projection

Source 2D Projection

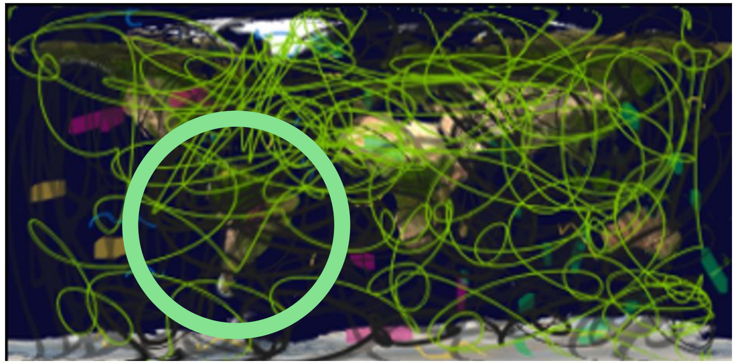
2D projection after registration

Rotated Source Sph. Image





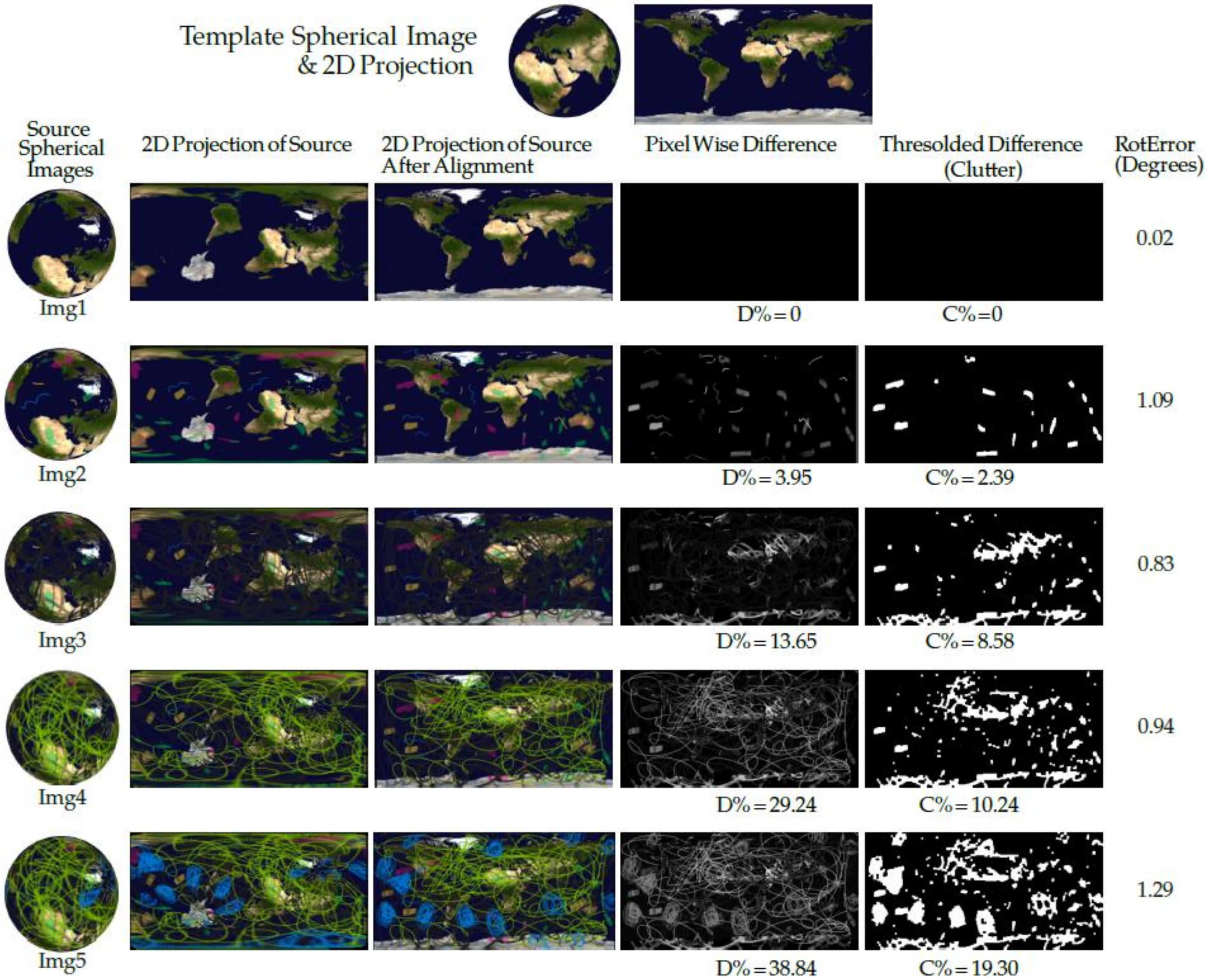
Rotated + Noisy Source Sph. image



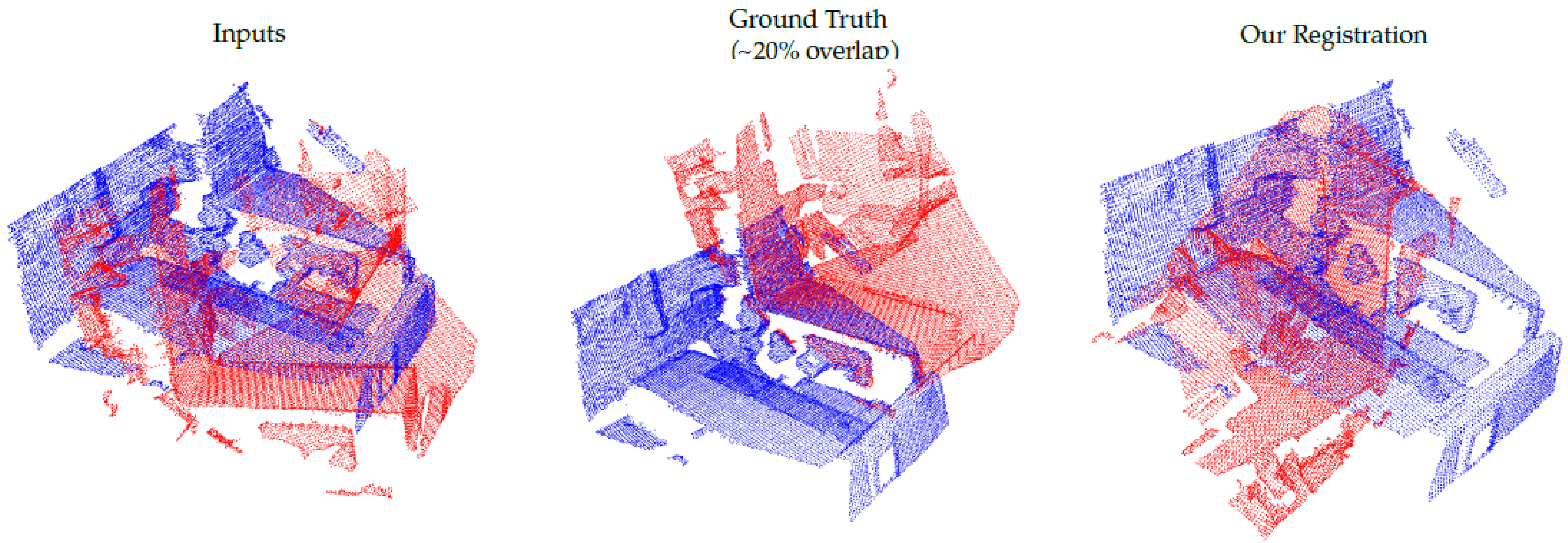
Evaluation:
Map Data

Our Method Clutter = 19%

	Rotation (deg)	Error (deg)
Alpha	55.27	0.20
Beta	12.11	0.21
Gamma	11.02	1.26



Limitation and Future Work



Point cloud registration depends on the quality of spherical embedding.

For partial clouds, rotation-invariant embeddings like EGI can be challenging, often requiring >65% overlap for partial-to-partial registration.

A future direction of this work is to improve rotation-invariant spherical embeddings for partial point clouds

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Summary

- We introduce two novel algorithms for spherical point- pattern registration, along with a third hybrid algorithm that combines the two.
- Our algorithm runs ~O(n) time complexity.
- We demonstrate the adaptability of our algorithms for point cloud registration. Additionally, we present the Centroid Aware Spherical Embedding (CASE) method, to convert a point cloud into spherical pattern.
- We propose a novel approach for converting spherical images to spherical point clouds, enabling tasks such as rotation estimation between two spherical images.
- We present the publicly available "Robust Vector Alignment Dataset," this can be used for evaluation of algorithms vector set alignment, spherical pattern alignment, Wahaab problem etc.

Thanks for watching

Webpage

Dataset & Code