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Robust Point Cloud Registration via Local-to-Global Geometric Feature Aggregation

Karim Slimani¹, Catherine Achard¹ and Brahim Tamadazte¹

This paper presents a hybrid descriptor for 3D point matching and point cloud registration. It combines local geometric properties with learning-based feature propagation to describe the neighbourhood structure of each point. The architecture first extracts prior geometric information by computing the planarity, anisotropy and omnivariance of each point using Principal Component Analysis (PCA). This information is augmented by a descriptor based on normal vectors estimated by a triangle-based shape construction. The main contributions are summarised in the following:

- Estimating a single normal vector for each point by weighting the normals of triangles formed with their nearest neighbours.
- Using local PCA to compute a local reference frame (LRF) and local geometric features such as anisotropy, omnivariance and planarity that are used to create a robust feature vector by combining them with 3D spatial coordinates.
- Ensure rotation invariant descriptors by projecting the normals into the LRFs.
- Propagate descriptor information from local to global using KNN-based graphs and a *self-attention* mechanism.

The proposed descriptor is evaluated on ModelNet40 and MVP-RG datasets and shows a good performance, especially on noisy and low overlapping point clouds. We use the same process as SOTA methods [1], [2] by constructing a similarity matrix as a result of a projection between the features of the two point clouds. The set of correspondences is built by collecting the mutual best scores from this matrix and used to estimate the rigid transformation thanks to the FSR module of [3]. Table I shows that our descriptor outperforms all tested methods on noisy and partially overlapping point clouds as it ranks first in the four used metrics on, tying with RoCNet++ in translation. Both methods outperform the second best (RoCNet [2] and GeoTransformer [4]) by 50% in RMSE and by 67% in MAE. Table II highlights that our method can handle very challenging configurations with varying local densities, low-overlapping point clouds, and unrestricted rotations $[0^\circ, 360^\circ]$, outperforming the other methods in all metrics by at least a 55% relative gap.

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¹ Authors are with ISIR, Sorbonne Université, CNRS UMR 7222, INSERM U1150, 4 place Jussieu, Paris, France karim.slimani@isir.upmc.fr

TABLE I
PERFORMANCES ON NOISY AND PARTIALLY OVERLAPPING DATA.

Method	RMSE(R)	MAE(R)	RMSE(t)	MAE(t)
ICP [5]	33.067	25.564	0.294	0.250
VRNet [6]	03.615	1.637	0.010	0.006
GeoTransf [4]	<u>00.915</u>	0.386	0.007	<u>0.003</u>
RoCNet [2]	01.810	0.620	<u>0.004</u>	<u>0.003</u>
RoCNet++ [3]	01.278	0.318	0.002	0.001
Ours	00.774	0.266	0.002	0.001

TABLE II
PERFORMANCES ON MULTI-VIEW PARTIAL VIRTUAL SCAN REGISTRATION (MVP-RG)

Method	L_R	L_t	L_{RMSE}
IDAM [7]	24.35°	0.280	0.344
RGM [8]	41.27°	0.425	0.583
DCP [9]	30.37°	0.273	0.634
RPMNet [10]	22.20°	0.174	0.327
GMCNet [11]	16.57°	0.174	0.246
Ours	07.33°	0.043	0.099

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