HeMoRa: Unsupervised Heuristic Consensus Sampling for Robust Point Cloud Registration

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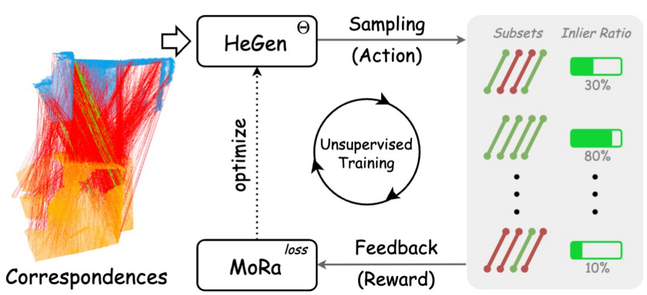
Background

Task: Minimal Set Sampling for Robust Point Cloud Registration (PCR).

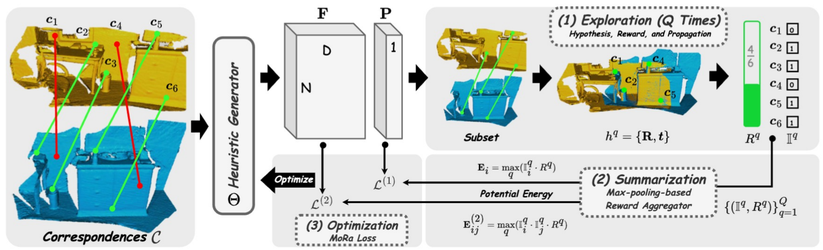
Challenge: While correspondence-based PCR has achieved promising results under supervision, **unsupervised rigid transformation estimation** remains a significant challenge due to the absence of ground-truth alignment for learning.



Inspiration: Reinforcement learning - agent learns through iterative actions and reward feedback.

Methodology

HeMoRa: an unsupervised training framework for robust estimation.



Three intuitive steps - ESO

(i) **Exploration:** HeGen explores a total of Q subsets.
(ii) **Summarization:** Experiences from Q rounds of exploration.
(iii) **Optimization:** The aggregated potential energy is used to guide the learning of sampling probabilities and features.

Efficient Policy Gradient Training

$$\frac{\partial}{\partial\Theta}\mathbb{E}_{q\sim\hat{\mathbf{P}}^q}[R^q] \approx \underbrace{\frac{\partial}{\partial\Theta}\sum_{i=1}^{N}\ln(\mathbf{P}_i)}_{\text{(i)}} \cdot \overbrace{\frac{1}{Q}\sum_{q=1}^{Q}\mathbb{I}_i^q \cdot R^q}^{\text{(ii)}},$$

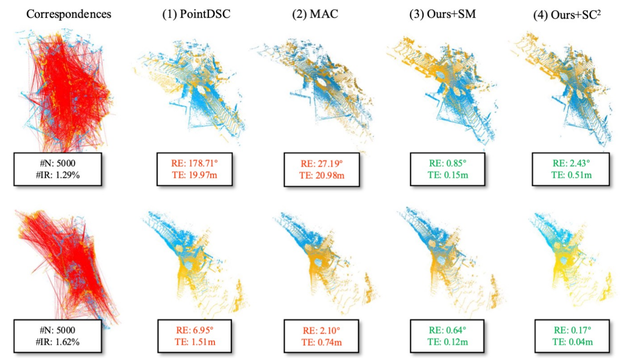
TERM (i) backpropagates the gradient.
TERM (ii) Integrates the feedback (reward) among Q samples.

$$\mathbb{I}_i^q = \mathbf{1}[r(\boldsymbol{c}_i, h^q) \le \tau], \qquad \mathbf{E}_i = \max_q(\mathbb{I}_i^q \cdot R^q)$$

Consistency-aware Reward Propagation ***Max-pooling-based Reward Aggregator***

Results

Qualitative comparison on KITTI-20m.



Results on 3DMatch: achieves competitive or superior performance compared to supervised baselines.

	Methods	Unsup-ervised	FPFH			FCGF		
			RR(%)	RE(°)	TE(cm)	RR(%)	RE(°)	TE(cm)
Traditional	TEASER++ [54]	-	75.48	2.48	7.31	85.77	2.73	8.66
	GC-RANSAC [5]	-	67.65	2.33	6.87	92.05	2.33	7.11
	RANSAC-1M [18]	-	64.20	4.05	11.35	88.42	3.05	9.42
	RANSAC-2M [18]	-	65.25	4.07	11.56	90.88	2.71	8.31
	RANSAC-4M [18]	-	66.10	3.95	11.03	91.44	2.69	8.38
	CG-SAC [43]	-	78.00	2.40	6.89	87.52	2.42	7.66
	SC²-PCR [10]	-	83.73	2.18	6.76	93.28	**2.08**	6.55
	MAC [66]	-	**83.92**	2.11	6.80	92.79	2.18	6.89
Learning	3DRegNet [39]	✗	26.31	3.75	9.60	77.76	2.74	8.13
	DGR [13]	✗	32.84	2.45	7.53	88.85	2.28	7.02
	DHVR [29]	✗	67.10	2.78	7.84	91.93	2.25	7.08
	DHVR-Origin [29]	✗	80.22	2.06	6.87	91.40	**2.08**	6.61
	PointDSC [4]	✗	77.57	2.03	**6.38**	92.85	**2.08**	6.51
	VBReg [25]	✗	82.75	2.14	6.77	93.10	2.33	6.68
Ours	Ours+PSAC	✓	72.21	4.32	7.77	92.79	4.22	6.12
	Ours+SM	✓	81.39	**2.01**	6.48	93.41	2.10	**6.07**
	Ours+SC²	✓	**83.92**	2.56	6.53	**93.65**	2.10	6.53