Supplementary Material: Rotation-Only Bundle Adjustment

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1. Other Error Metrics on Synthetic Datasets

In the main paper, we compared the rotational accuracy of RA and ROBA (initialized by RA) in terms of the mean angular error after the L_1 alignment. Here, we show additional comparisons in other metrics, namely the median angular error after the L_1 alignment, and the mean/median angular error after the L_2 alignment. Fig. 1–3 and Table 1 present the results. With these additional metrics, we reach the same conclusion as in the main paper. That is,

1. ROBA improves the results of RA in all scenarios considered.
2. Both RA and ROBA yield more accurate results for fewer views, farther points and pure rotations, all of which lead to a denser view-graph. In these cases, the relative error reduction by ROBA is also larger.

2. Evolution of Total Cost and Rotation Errors on Real Datasets

In Fig. 4, we plot the evolution of the relative errors aggregated from all 15 real-world datasets. Notice that most of the improvement occurs in less than 50 iterations. In Fig. 5–19, we show the evolution of the total cost and the different rotation error metrics for each dataset. We make the following observations:

1. The cost always overshoots after the first rotation update. From the second update onward, it starts decreasing with occasional "mini" overshoots. From additional experiments, we found that reducing the step size α in the Adam optimizer prevents this overshoot, but this leads to a slower rate of convergence. Interestingly, the overshoot of the total cost does not necessarily lead to the overshoot of the rotation errors.
2. On most datasets, the cost converges after 30–40 iterations. However, a relatively small change in the total cost can sometimes lead to a non-negligible change in the angular errors. For example, see the results for MDR, PDP and TOL in Fig. 8, 12, 15 after 40 iterations.
3. For ROF dataset in Fig. 14, the final total cost after 100 iterations is larger than the initial total cost. However, all of the rotation error metrics are reduced.

These observations indicate that there is a discrepancy between the total cost and the rotation errors. This suggests that when we implement the stopping criteria for the iterations, we need to consider not only the change in the total cost, but also the number of iterations and the angular change in the rotations.

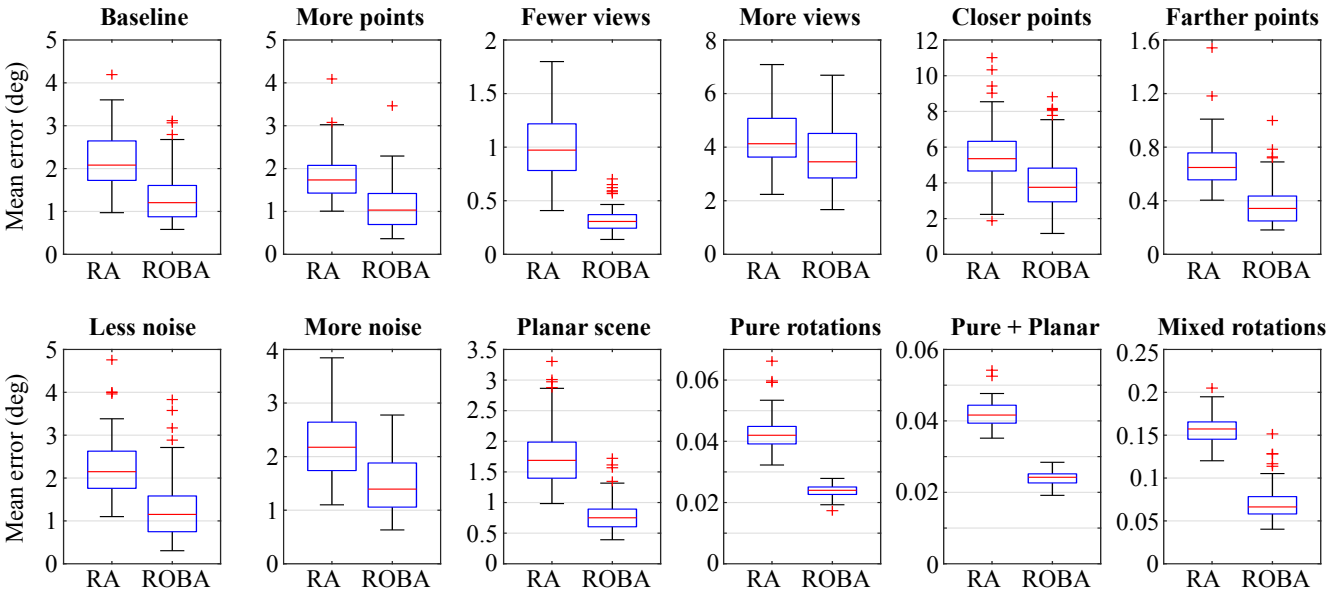

Figure 1. **[Synthetic - md1]** Comparison of RA and ROBA (initialized by RA) in terms of the median angular error after L_1 alignment.

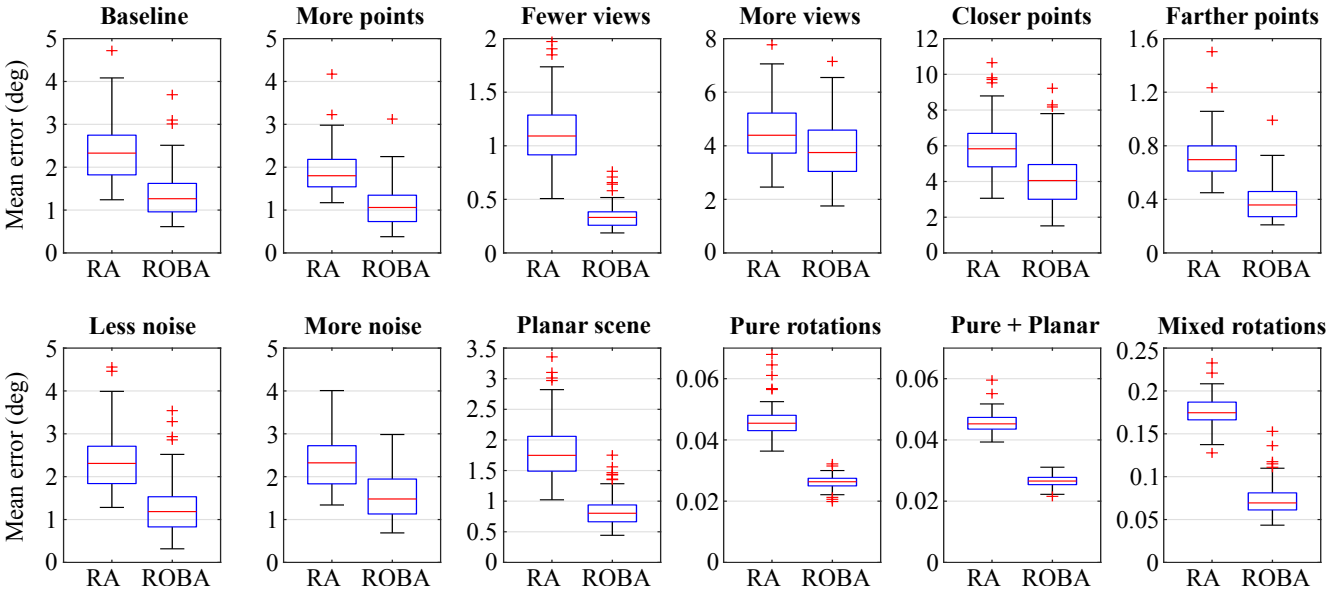

Figure 2. **[Synthetic - mn2]** Comparison of RA and ROBA (initialized by RA) in terms of the mean angular error after L_2 alignment.

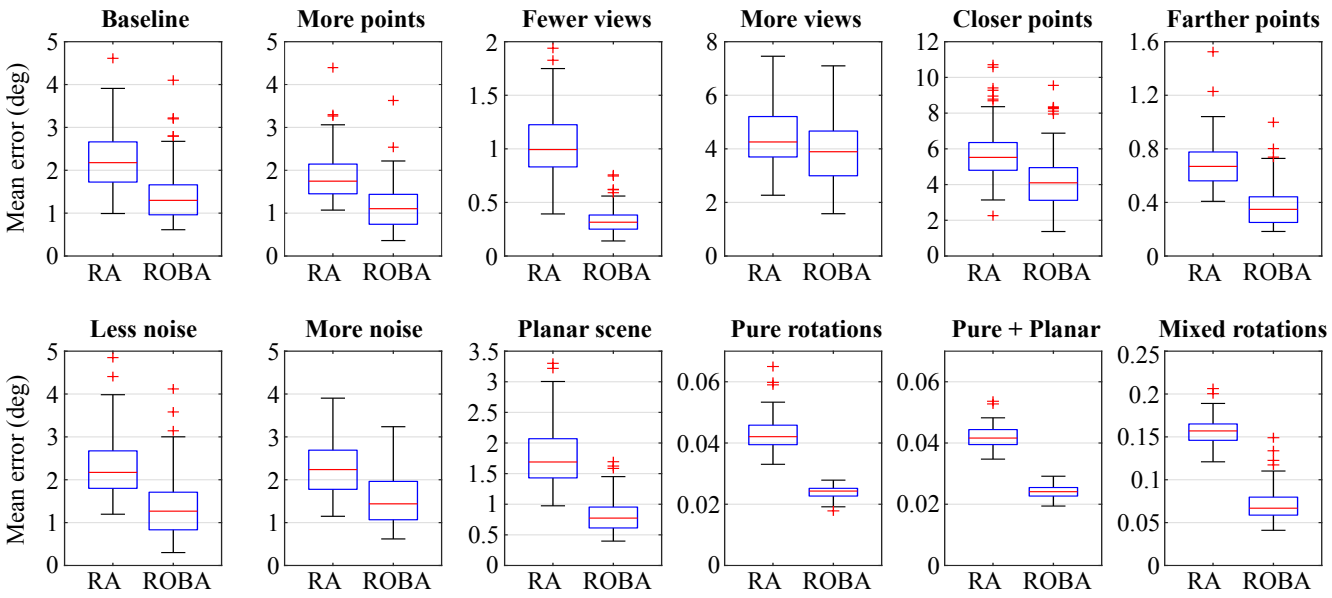

Figure 3. **[Synthetic - md2]** Comparison of RA and ROBA (initialized by RA) in terms of the median angular error after L_2 alignment.

Settings	$\%_\mathcal{E}$	$\bar{e}_\mathcal{E}$	$\tilde{e}_\mathcal{E}$	RA				RA + ROBA (100 iter)				$\%_{\text{better}}$			
				mn1	md1	mn2	md2	mn1	md1	mn2	md2	mn1	md1	mn2	md2
Baseline	6.0%	2.21	1.39	2.31	2.08	2.33	2.18	**1.26**	**1.20**	**1.26**	**1.30**	100%	99%	100%	100%
More points	7.2%	2.51	1.52	1.78	1.73	1.80	1.75	**1.05**	**1.03**	**1.06**	**1.10**	100%	100%	100%	100%
Fewer camera	21%	2.23	1.38	1.08	0.97	1.09	0.99	**0.33**	**0.31**	**0.33**	**0.32**	100%	100%	100%	100%
More views	2.0%	2.24	1.40	4.35	4.13	4.39	4.26	**3.73**	**3.45**	**3.75**	**3.89**	100%	98%	100%	97%
Closer points	4.0%	2.57	1.65	5.74	5.35	5.83	5.52	**3.99**	**3.75**	**4.05**	**4.10**	100%	97%	100%	99%
Farther points	10%	1.97	1.22	0.69	0.65	0.70	0.67	**0.36**	**0.34**	**0.36**	**0.35**	100%	100%	100%	100%
Less noise	6.0%	2.25	1.40	2.30	2.15	2.31	2.17	**1.17**	**1.15**	**1.19**	**1.27**	100%	99%	100%	100%
More noise	5.9%	2.23	1.38	2.31	2.17	2.32	2.24	**1.48**	**1.39**	**1.48**	**1.44**	100%	98%	100%	99%
Planar scene	7.4%	2.61	1.56	1.74	1.69	1.75	1.69	**0.80**	**0.75**	**0.80**	**0.77**	100%	100%	100%	100%
Pure rotations	100%	0.89	0.74	0.045	0.042	0.045	0.042	**0.026**	**0.024**	**0.026**	**0.024**	100%	100%	100%	100%
Pure + Planar	100%	0.89	0.74	0.045	0.042	0.045	0.042	**0.027**	**0.024**	**0.027**	**0.024**	100%	100%	100%	100%
Mixed rotations	37%	3.13	1.66	0.17	0.16	0.17	0.16	**0.069**	**0.066**	**0.069**	**0.067**	100%	100%	100%	100%

$\%_\mathcal{E}$, $\%_{\text{better}}$: proportion of existing edges and improved results,
$\bar{e}_\mathcal{E}$, $\tilde{e}_\mathcal{E}$: mean and median angular errors (in deg) of the relative rotations from all edges.

Table 1. **[Synthetic datasets]** Median results of the 100 simulations in each setting.

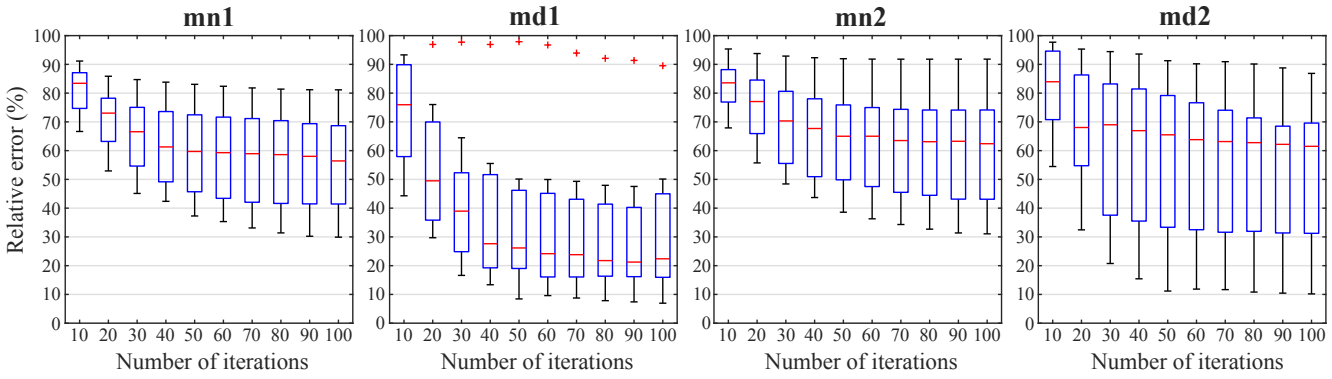

Figure 4. **[Real datasets]** Relative errors with respect to the initial errors. mn/md/1/2: mean/median angular error after L_1/L_2 alignment.

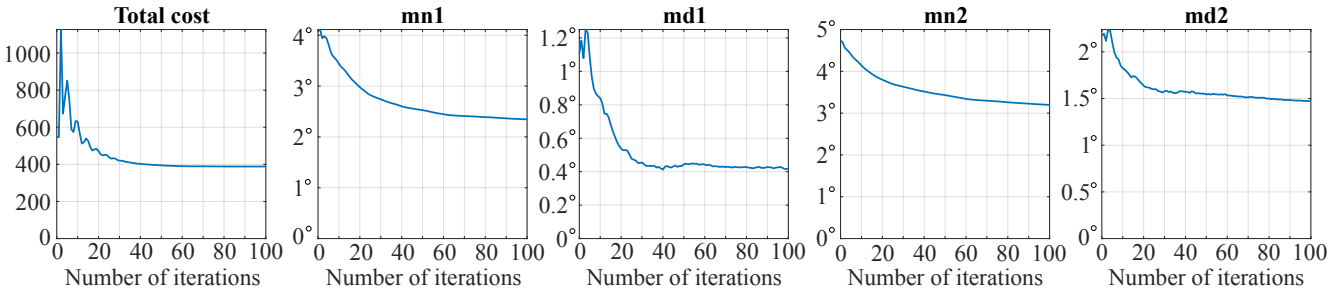

Figure 5. **[ALM - Alamo]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

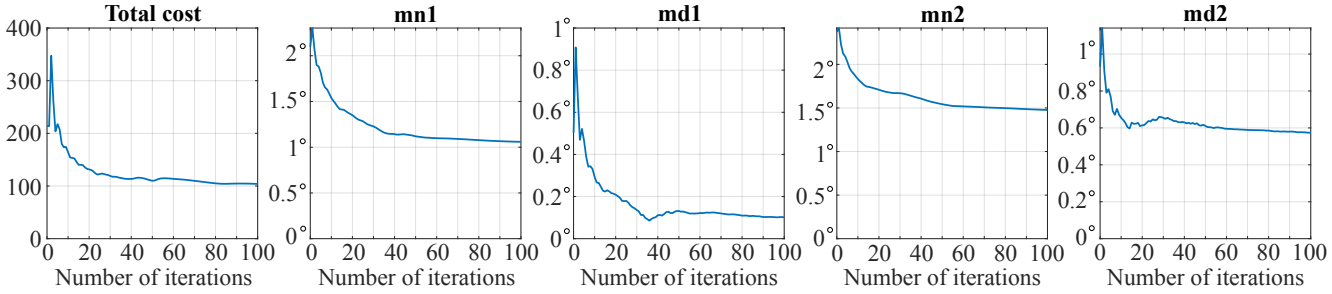

Figure 6. **[ELS - Ellis Island]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

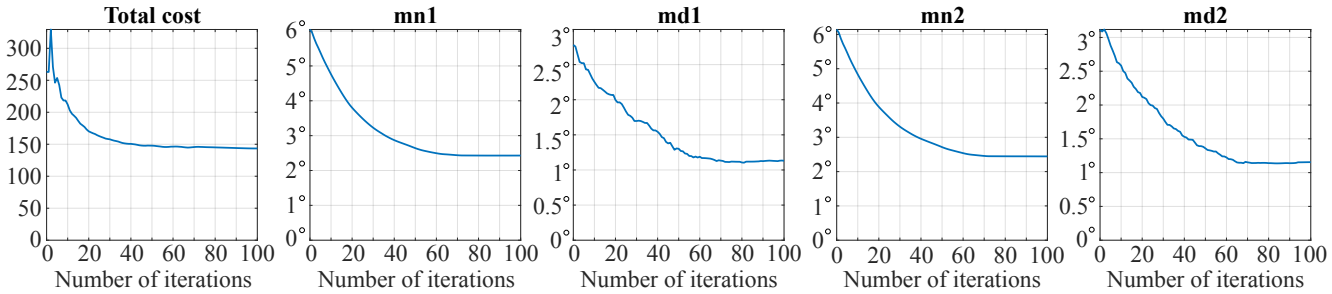

Figure 7. **[GDM - Gendarmenmarkt]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

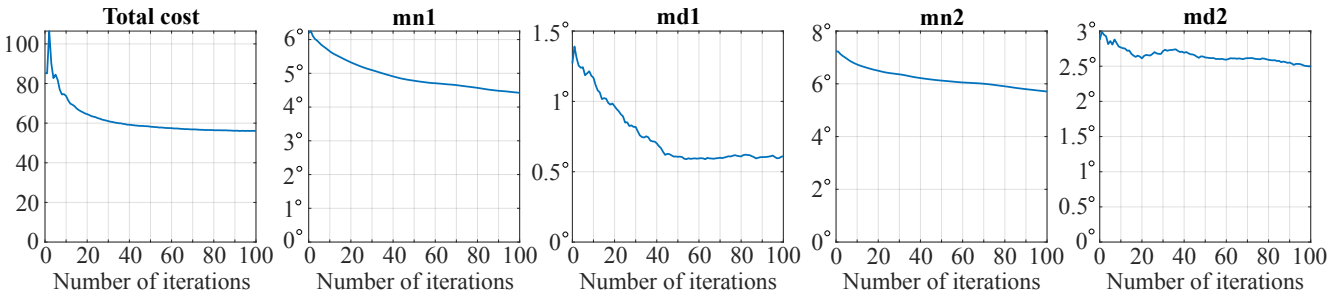

Figure 8. **[MDR - Madrid Metropolis]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

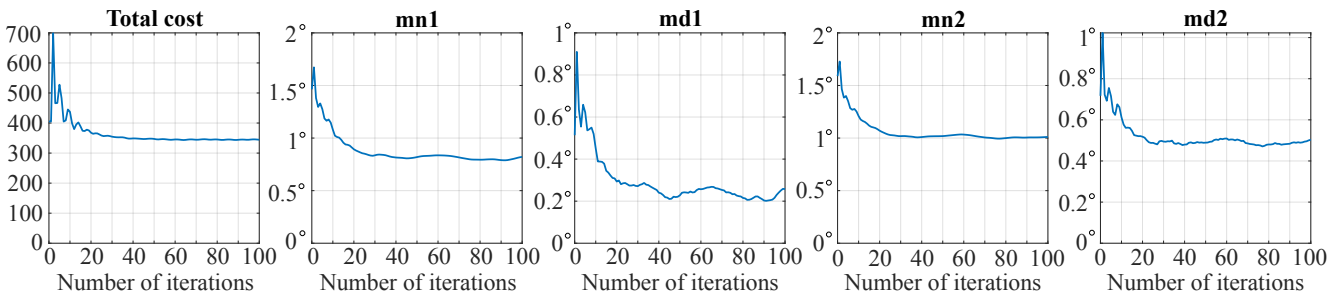

Figure 9. **[MND - Montreal Notre Dame]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

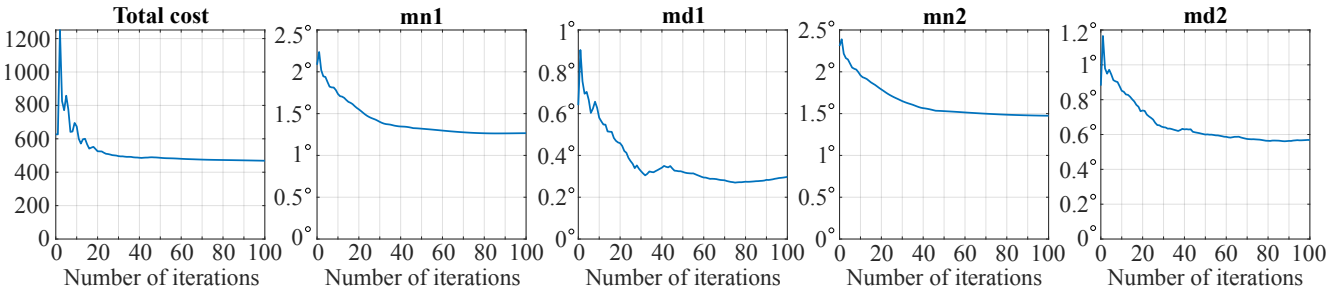

Figure 10. **[NTD - Notre Dame]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

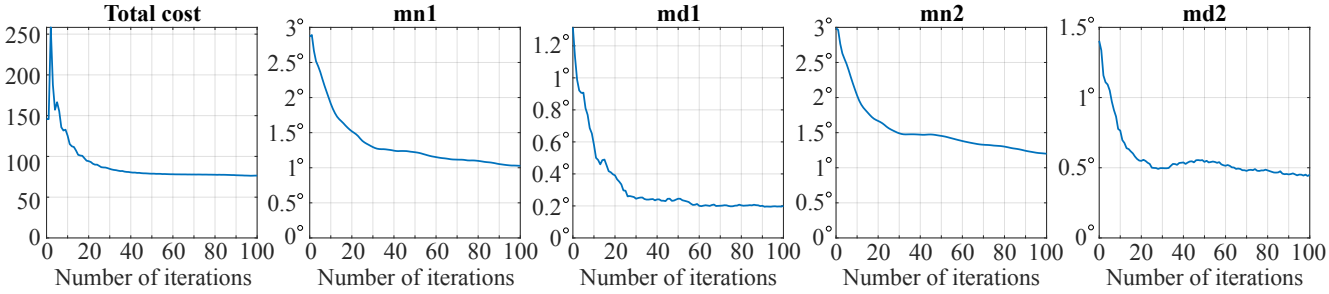

Figure 11. **[NYC - NYC Library]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

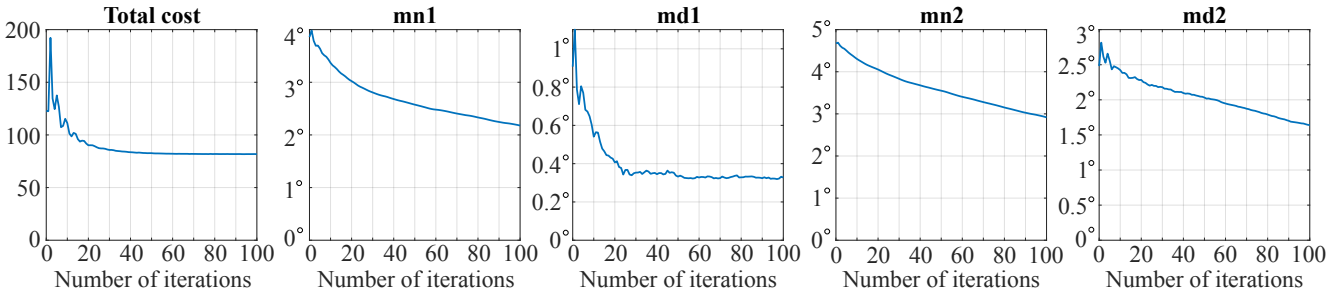

Figure 12. **[PDP - Piazza del Popolo]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

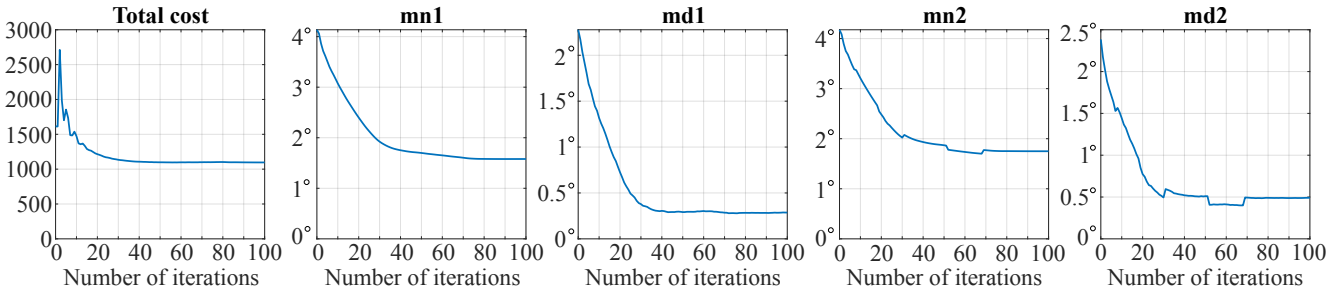

Figure 13. **[PIC - Picadilly]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

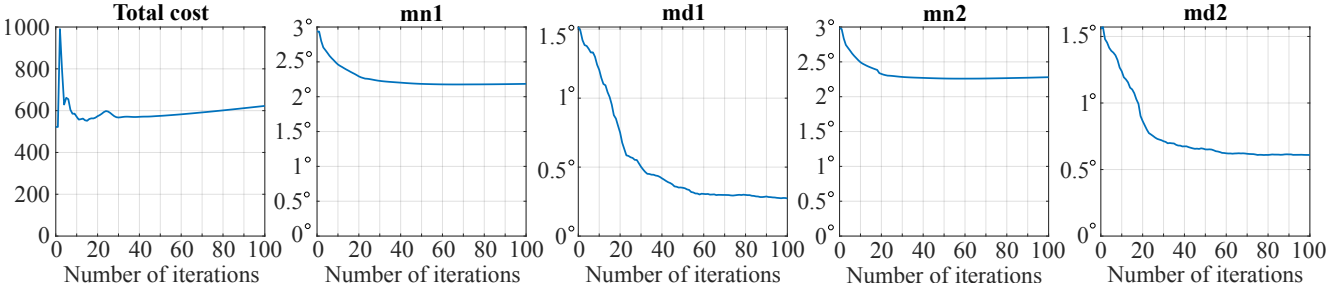

Figure 14. **[ROF - Roman Forum]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

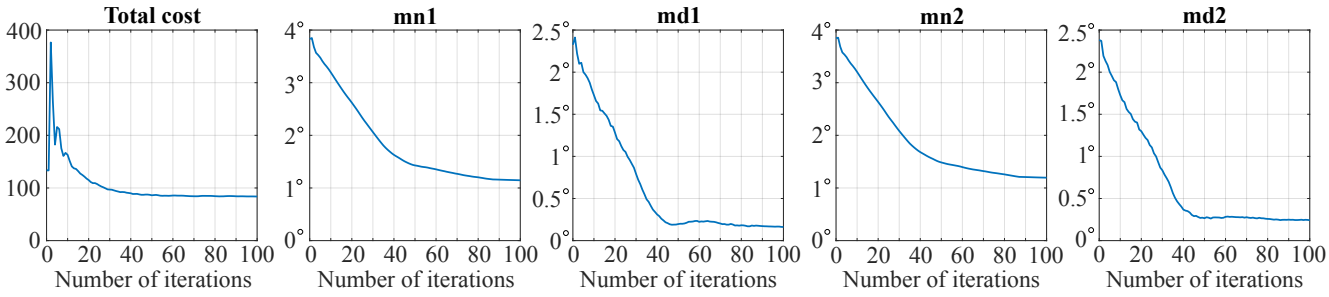

Figure 15. **[TOL - Tower of London]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

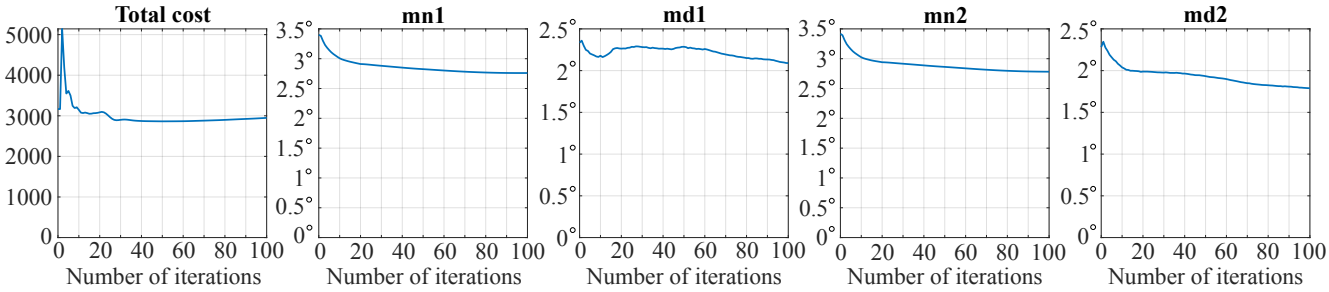

Figure 16. **[TFG - Trafalgar]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

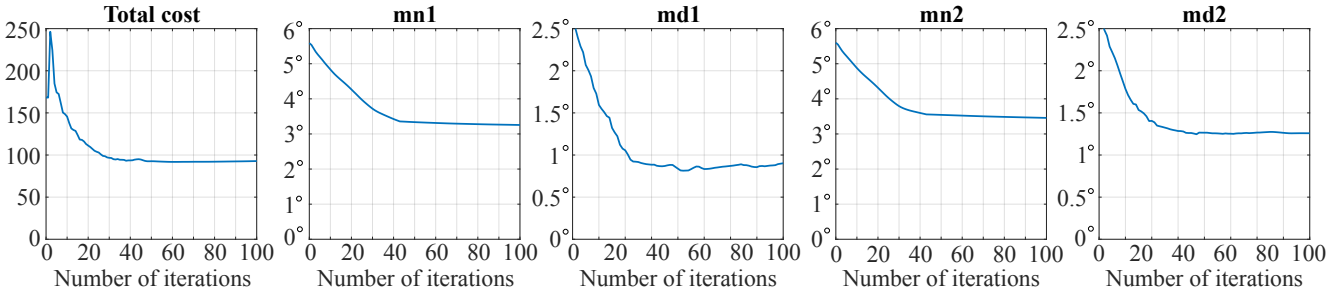

Figure 17. **[USQ - Union Square]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

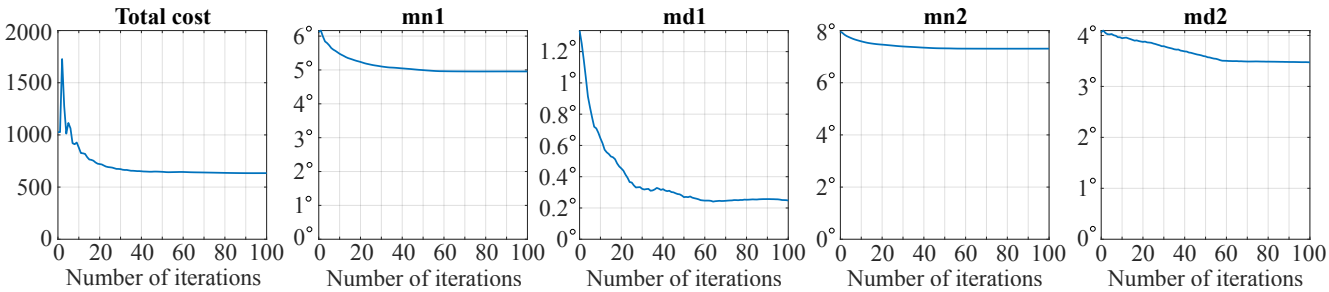

Figure 18. **[VNC - Vienna Cathedral]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,

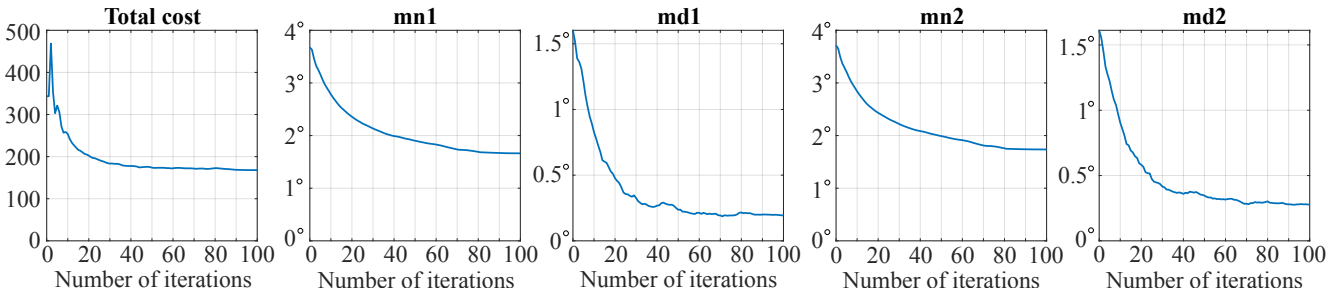

Figure 19. **[YKM - Yorkminster]** mn/md/1/2: mean/median angular error (in deg) after the L_1/L_2 alignment,