Supplementary Figures and Tables:
Direct Multichannel Tracking

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1. Qualitative Results

1.1. General Notes

- We only provide qualitative results for those experiments in which the tracker surpassed the initialization phase (5 first keyframes as specified by the baseline implementation, LSD-SLAM).

- Visualization scales are the same for all experiments on a given sequence, and all use the `viewer`'s default settings.

- The included video file `DMT-videos.m4v` compiles several video clips showing a side-by-side comparison between the baseline experiment (single-channel grayscale tracking) versus the best result achieved via direct multichannel tracking (subjective decision). We show:

Timeline position	Features comparison	Dataset	Sequence
00:04	Gray vs. AlexNet	LSD-SLAM	Room
00:55	Gray vs. AlexNet	LSD-SLAM	Machine
02:08	Gray vs. AlexNet	LSD-SLAM	ECCV
03:35	Gray vs. AlexNet	KITTI	Nº 09
04:24	Gray vs. SIFT	ICL-NUIM	Living Room Nº 02

- Video clips are sped-up to different arbitrary rates for easier visualization.

- Videos are not synchronized because tracking speeds differ for each method and there exists scale ambiguity among the results.

Activation Depth Maps:

- Negative inverse depth is visualized in white.

- The figures in this section are examples at various times arbitrarily selected.

- For the prominent results, the entire sequence of depth maps are included with the corresponding point cloud video clips.

3D Point Clouds:

- The camera's path (trajectory) is visualized in green.

- The current camera frame (end frame for figures here) are visualized in red.

- The figures in this section are the final screenshots from the accumulated point clouds.

- Visualization scales are the same for all experiments on a given sequence.

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*This work was done while interning at MERL.

1.2. Activation Depth Maps

1.2.1 TUM DSO Dataset

(a) Gray   (b) SIFT   (c) AlexNet
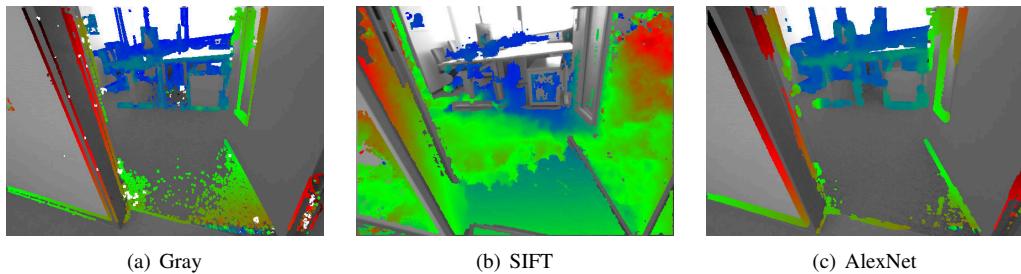
Figure 1. Depth map activation examples at $\mathbf{D}_{1500}$ for Seq. N° 07.

(a) Gray   (b) SIFT   (c) AlexNet
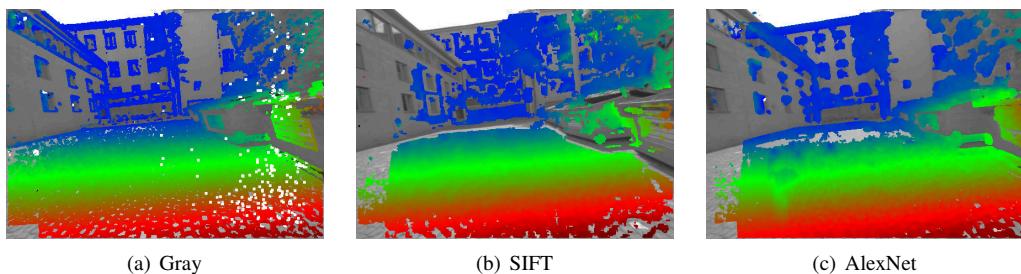
Figure 2. Depth map activation examples at $\mathbf{D}_{2000}$ for Seq. N° 33.

1.2.2 ICL-NUIM Dataset

(a) Gray   (b) SIFT   (c) AlexNet
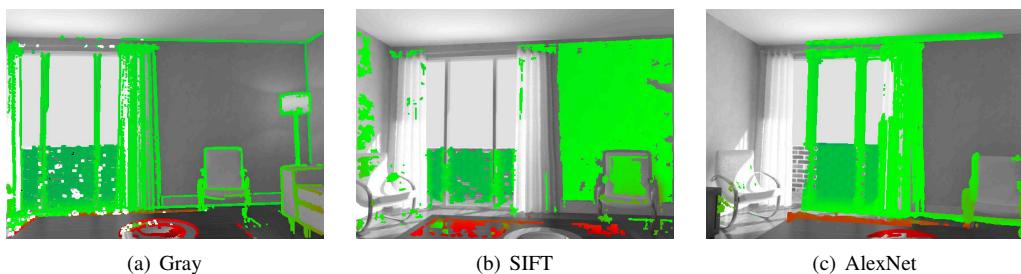
Figure 3. Examples at $\mathbf{D}_{500}$ for the `Living Room` sequence N° 02.

(a) Gray   (b) Siamese   (c) RGB
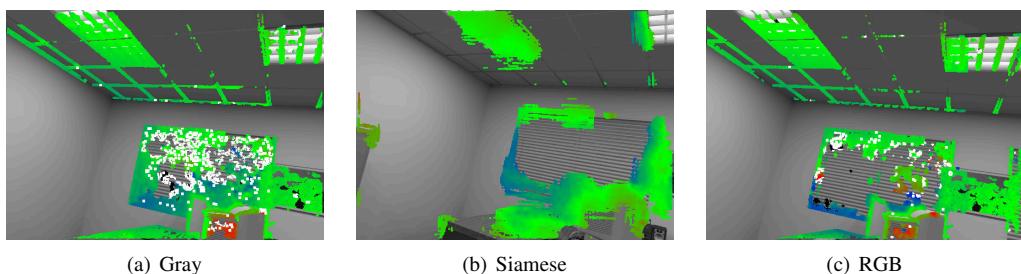
Figure 4. Examples at $\mathbf{D}_{500}$ for the `Office` sequence N° 03.

1.2.3 LSD-SLAM Dataset

(a) Gray   (b) SIFT   (c) AlexNet
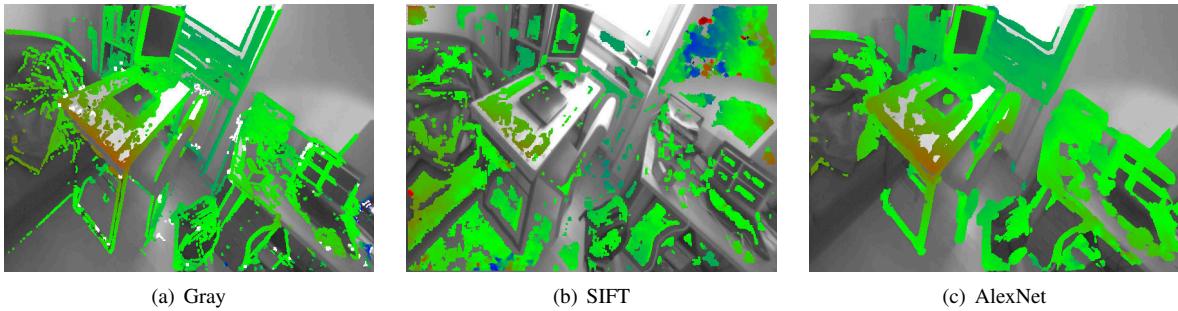
Figure 5. Depth map activation examples at $\mathbf{D}_{300}$ for the `Room` sequence.

(a) Gray   (b) SIFT   (c) AlexNet
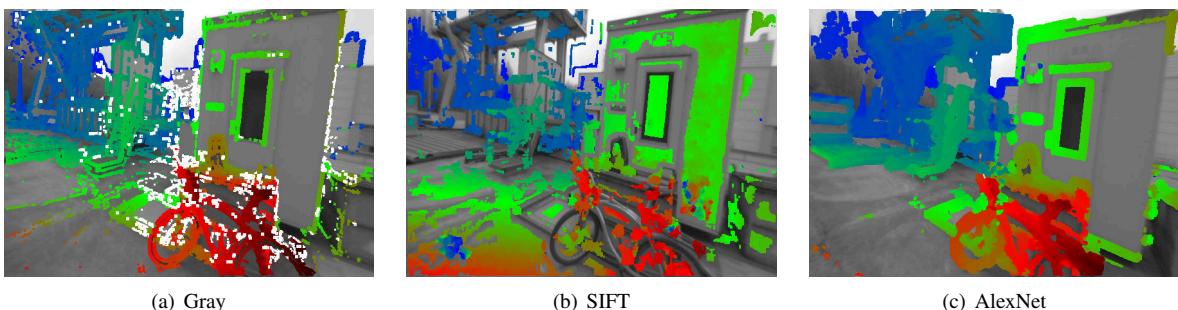
Figure 6. Depth map activation examples at $\mathbf{D}_{4000}$ for the `Machine` sequence.

(a) Gray   (b) SIFT   (c) AlexNet
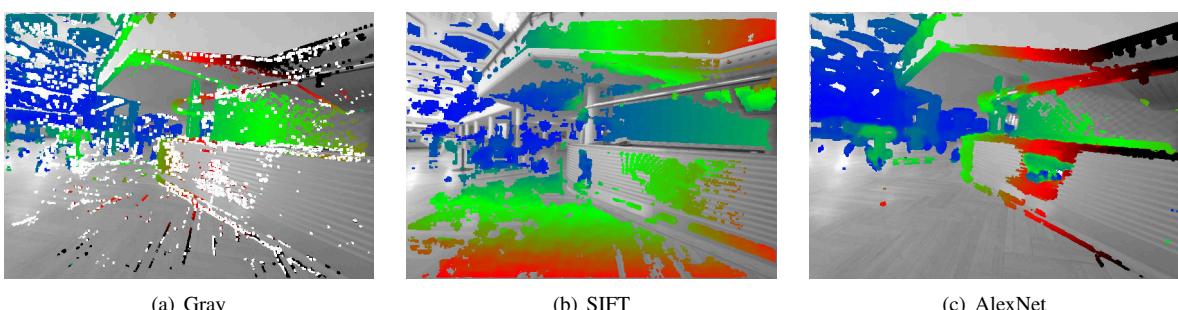
Figure 7. Depth map activation examples at $\mathbf{D}_{6000}$ for the `ECCV` sequence.

(a) Gray   (b) SIFT   (c) AlexNet
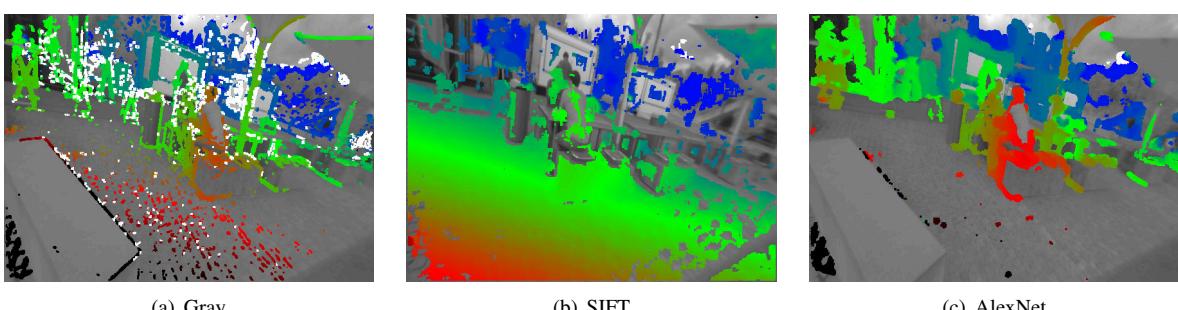
Figure 8. Depth map activation examples at $\mathbf{D}_{8000}$ for the `Foodcourt` sequence.

1.2.4 KITTI Dataset

(a) Gray

(b) SIFT

(c) AlexNet
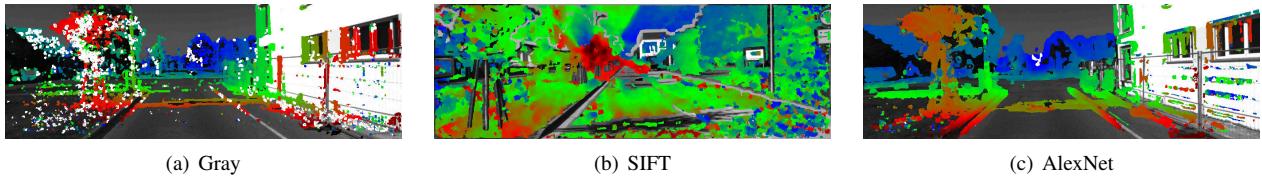
Figure 9. Depth map activation examples at $\mathbf{D}_{250}$ for the KITTI sequence N° 06.

(a) Gray

(b) SIFT

(c) AlexNet
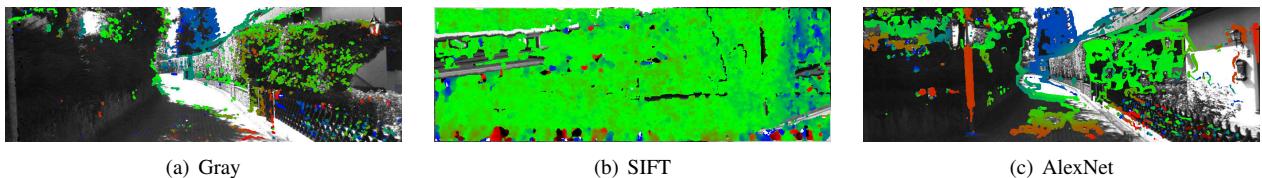
Figure 10. Depth map activation examples at $\mathbf{D}_{175}$ for the KITTI sequence N° 10.

1.2.5 Tsukuba Dataset

(a) Gray

(b) Lab

(c) RGB

(d) Bit-Planes

(e) SIFT
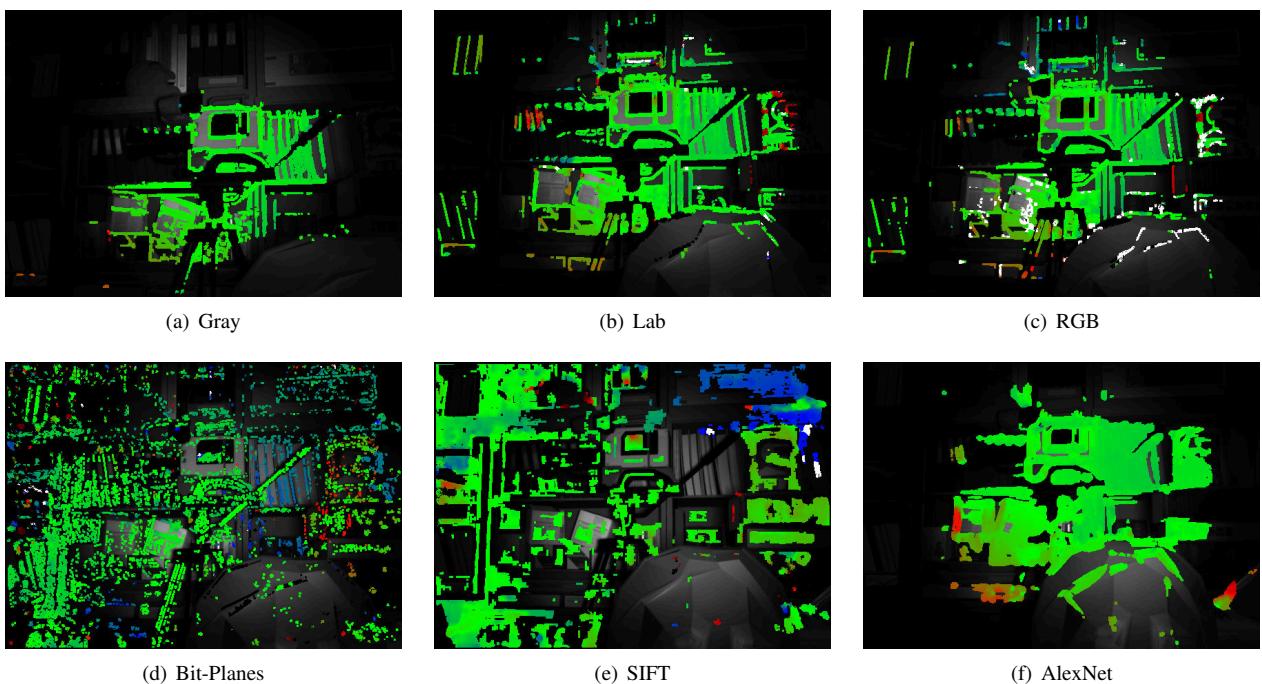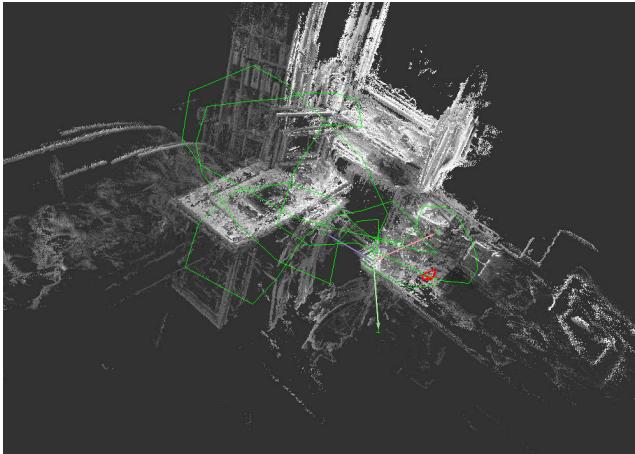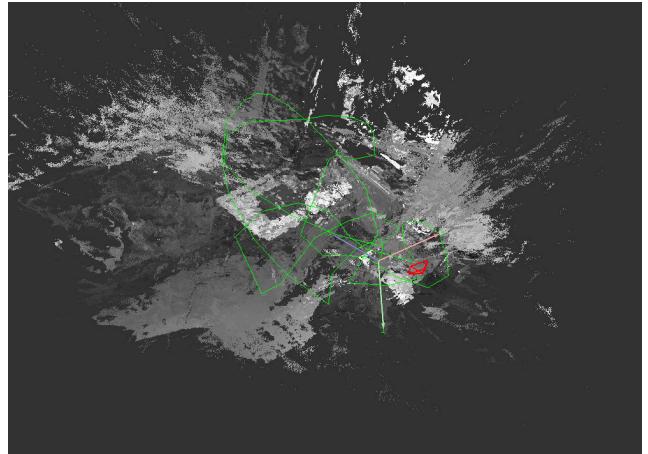
(f) AlexNet

Figure 11. Examples at $\mathbf{D}_{150}$ for the Tsukuba `flashlight` sequence, which simulates a challenging illumination condition.

1.3. 3D Point Clouds
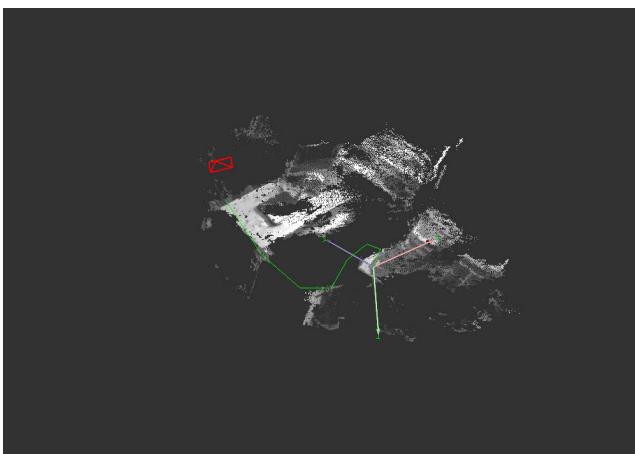
1.3.1 LSD-SLAM Dataset
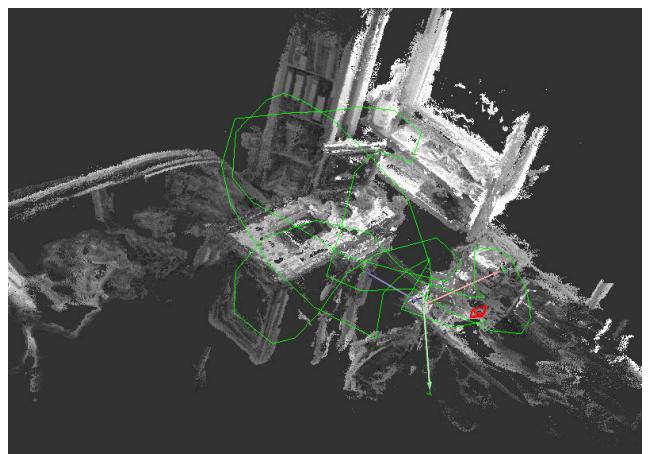
(a) Gray (baseline case)

(b) SIFT

(c) Siamese
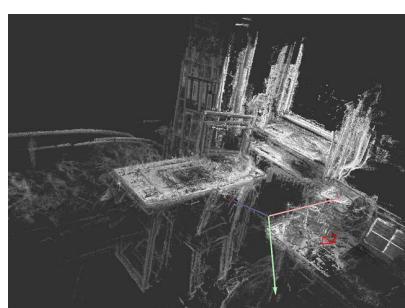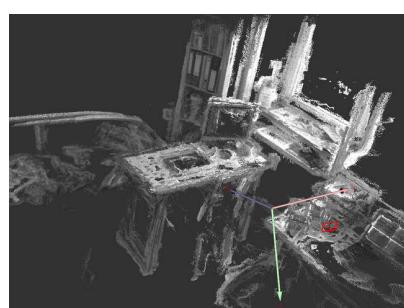
(d) AlexNet

Figure 12. 3D point clouds for the Room sequence from the LSD-SLAM dataset.

(a) Intensity image at $t = 150$
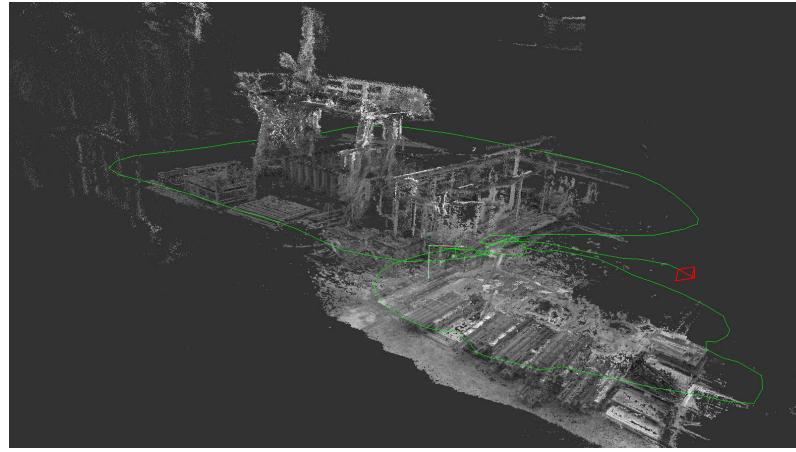
(b) Point cloud using Gray (baseline case)
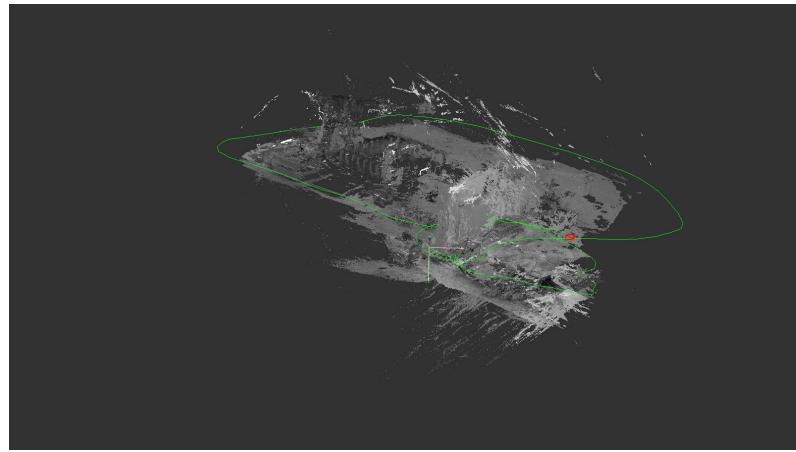
(c) Point cloud using AlexNet
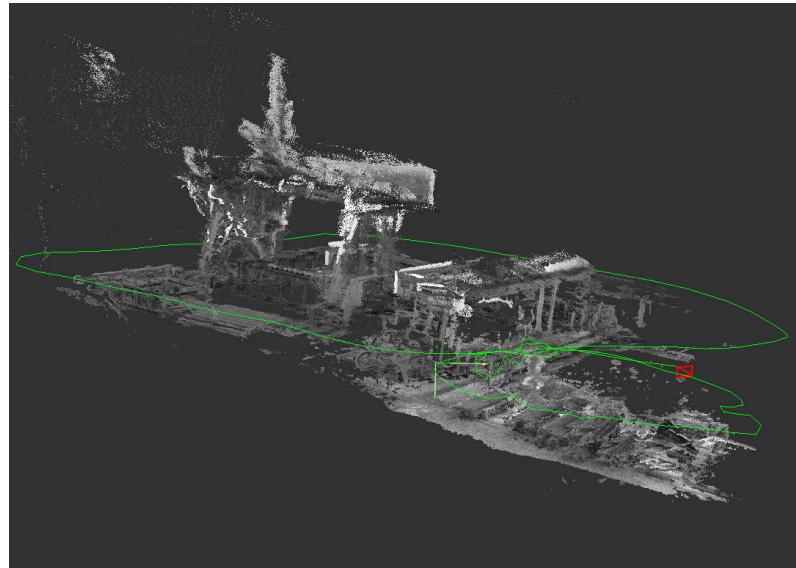
Figure 13. 3D point cloud comparison for the Room sequence from the LSD-SLAM dataset. Observe the higher accuracy achieved via the AlexNet features for reconstructing furniture, books, computer monitor, among other objects.

(a) Gray (baseline case)
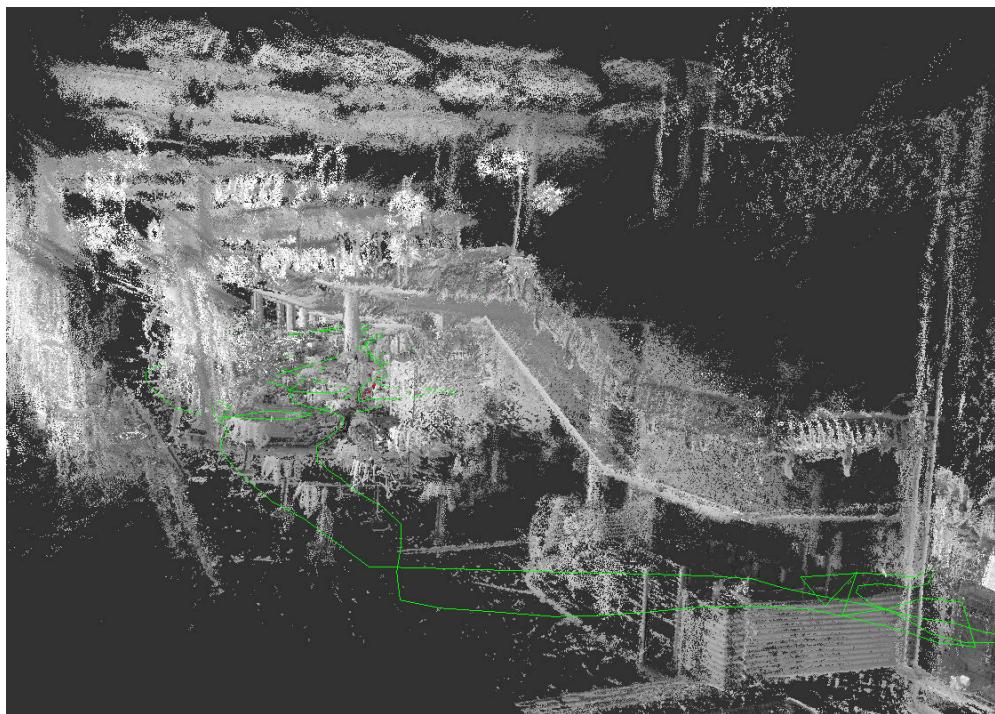
(b) SIFT
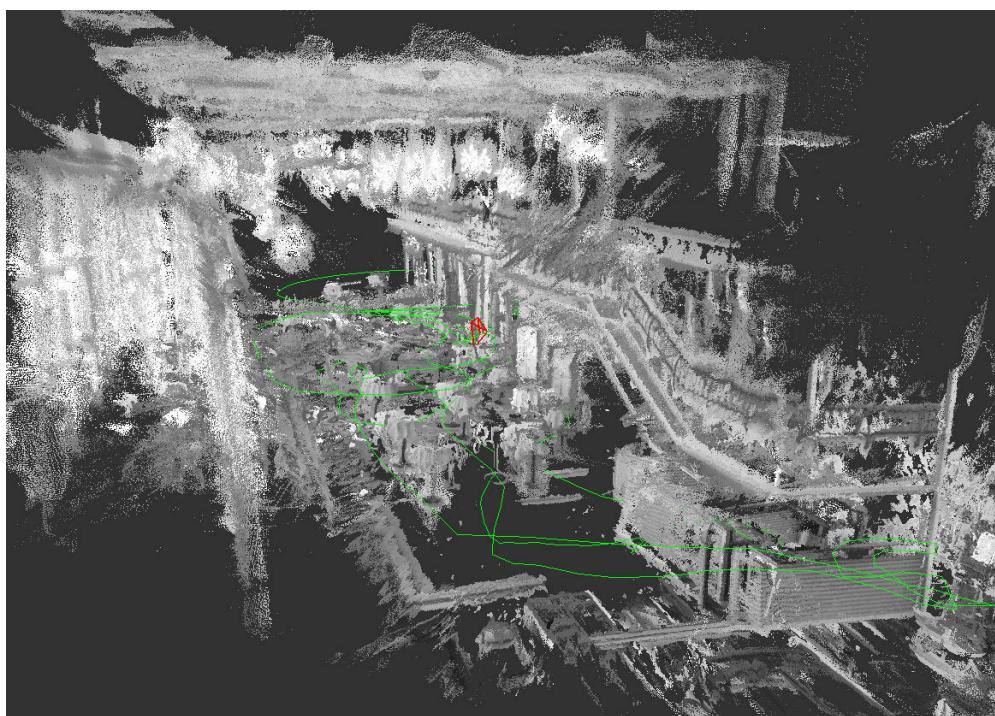
(c) AlexNet

Figure 14. 3D point clouds for the `Machine` sequence from the LSD-SLAM dataset. Although the generated point cloud for SIFT seems incomplete, it is nearsighted (denser at the camera-level surfaces close to the ground). The point cloud density achieved via AlexNet features appears very comparable to the grayscale experiment.
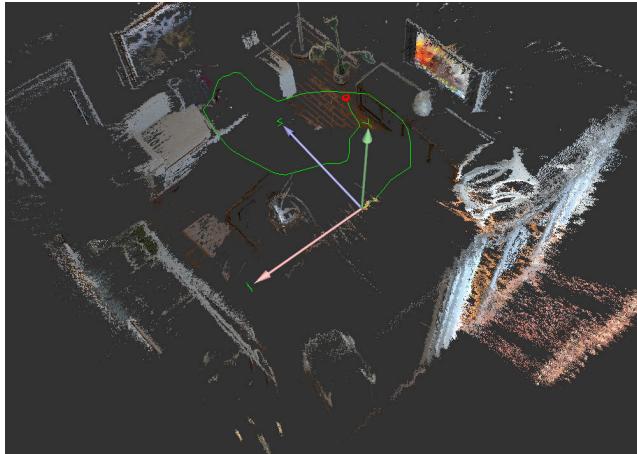
(a) Gray (baseline case)
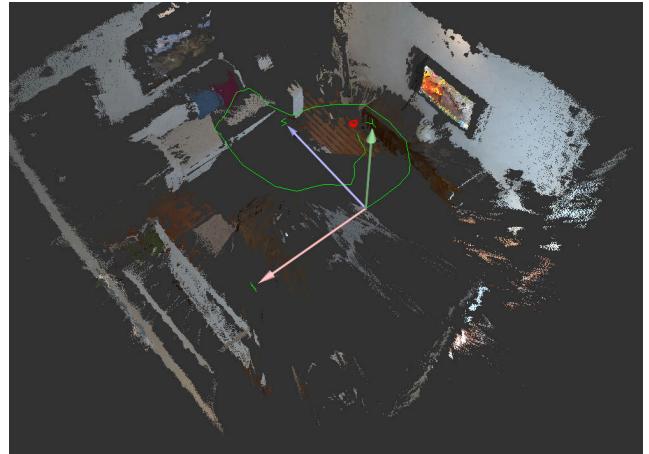
(b) AlexNet

Figure 15. 3D point clouds for the `ECCV` sequence from the LSD-SLAM dataset. The model with the AlexNet feature is more complete and accurate, such is the case for ceilings, walls, staircase, and tables.
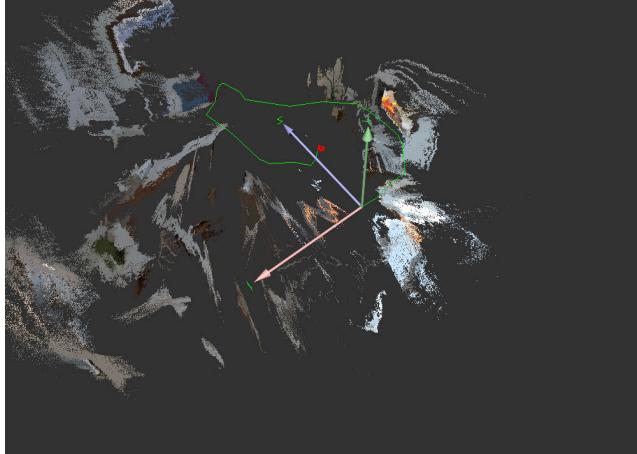
1.3.2 ICL-NUIM Dataset
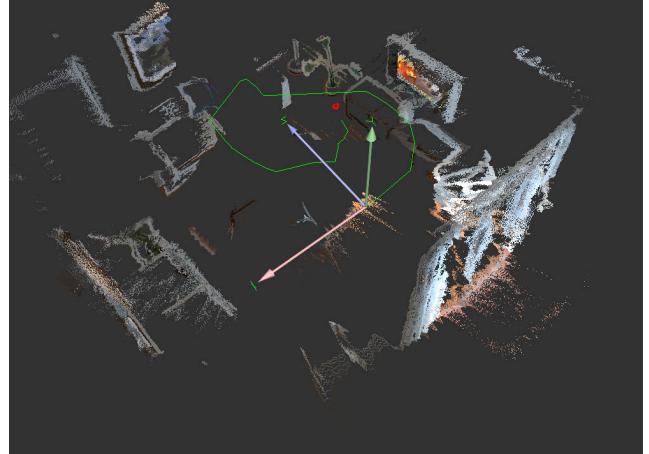
(a) Gray (baseline case)

(b) SIFT

(c) Siamese
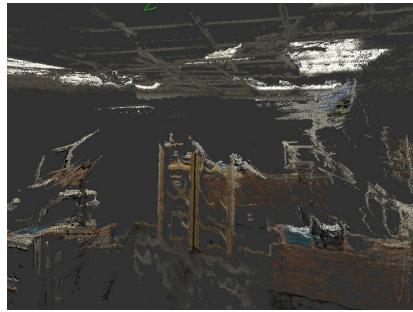
(d) AlexNet

Figure 16. 3D point clouds for the `Living Room` Seq. Nº 02 from the ICL-NUIM dataset. We chose this scene because all experiments completed the sequence successfully.

(a) Color image at $t = 0$

(b) Point cloud using Gray (baseline case)

(c) Point cloud using AlexNet

Figure 17. 3D point cloud comparison for the `Office` Seq. Nº 00 from the ICL-NUIM dataset. AlexNet features produced a denser and more accurate reconstruction (seen from similar viewpoints). For example, the computer desks, file cabinets, and ceiling regions are better aligned for the most part.

2. Error Analysis: Tables and Plots

2.1. General Notes

- Bold values in tables indicate the best value obtained for a particular sequence

2.2. Experimental Parameters

Table 1. Feature default scales.

Feature	Bit-Planes	SIFT	Siamese	AlexNet
Default Scale	9.77	0.68	347.50	1.23

2.3. Complete Numerical Results for the ICL-NUIM dataset

Table 2. Number of tracked frames for ICL-NUIM `Living Room` sequences.

| Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	829	829	**1509**	**1509**	829	843	830	792
01	169	171	**966**	**966**	158	763	183	151
02	**881**	**881**	**881**	**881**	**881**	**881**	**881**	344
03	564	567	**1241**	**1241**	410	567	566	366
Global Average	611	612	**1149**	**1149**	570	764	615	413

Table 3. Overall rotation errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for ICL-NUIM `Living Room` sequences.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	4.58	5.81	2.62	**1.21**	5.07	2.44	4.43	3.72
01	9.75	7.87	**2.31**	5.33	10.76	8.27	41.16	29.17
02	1.34	0.90	0.63	0.90	2.38	1.12	1.21	**0.58**
03	4.15	5.40	8.39	**1.41**	4.16	18.40	3.69	15.35
Global Average	4.95	5.00	3.48	**2.21**	5.59	7.56	12.62	12.20

Table 4. Overall translation angle errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for ICL-NUIM `Living Room`.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	31.81	33.18	7.15	**3.36**	29.29	18.77	33.44	29.84
01	136.93	120.14	**12.06**	61.20	122.83	108.31	311.27	302.38
02	2.93	2.15	**1.33**	1.53	6.81	2.59	3.24	1.66
03	3.74	8.90	7.24	**2.05**	5.53	23.43	3.38	27.10
Global Average	43.85	41.09	**6.94**	17.04	41.12	38.28	87.83	90.25

Table 5. Overall ATE mean in [meters] for ICL-NUIM `Living Room`.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	0.09	0.08	0.06	**0.03**	0.11	0.06	0.11	0.10
01	0.01	**0.01**	0.01	0.21	0.01	0.27	0.02	0.01
02	0.10	0.07	0.04	0.06	0.23	0.08	0.11	**0.01**
03	0.08	0.15	1.13	0.46	**0.05**	0.39	0.07	0.18
Global Average	**0.07**	0.08	0.31	0.19	0.10	0.20	0.08	0.07
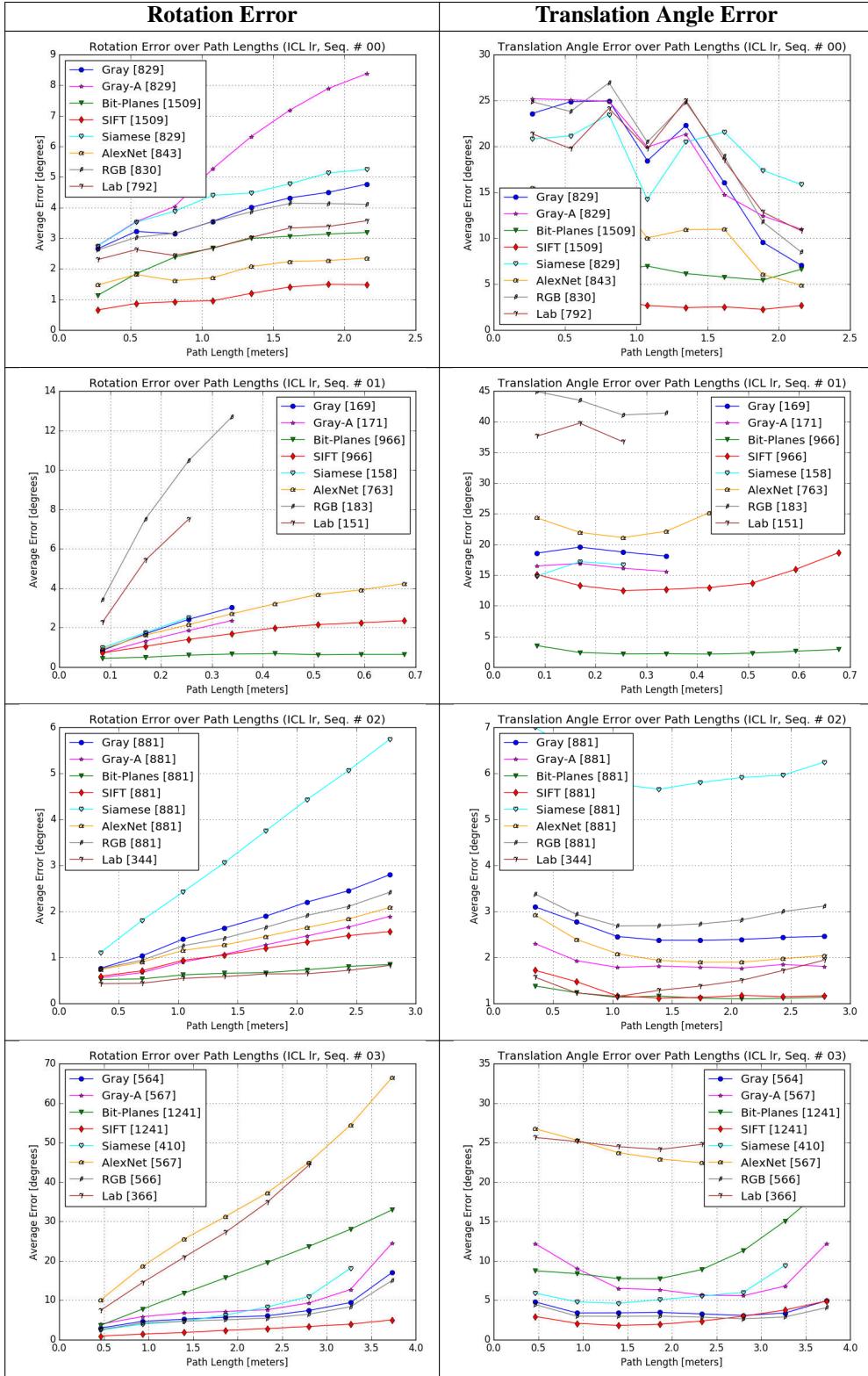
Figure 18. Rotation and translation angle error plots for all ICL `Living Room` sequences.

Table 6. Number of tracked frames for ICL-NUIM `Office` sequences.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	**1508**	**1508**	1241	769	983	1041	**1508**	429
01	**566**	559	232	142	542	546	565	432
02	341	343	341	330	**388**	346	344	337
03	**1241**	**1241**	**1241**	341	**1241**	**1241**	**1241**	1099
Global Average	914	913	764	396	788	794	**914**	574

Table 7. Overall rotation errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for ICL-NUIM `Office` sequences.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	8.00	5.26	3.36	**2.02**	3.43	7.26	5.04	20.62
01	**0.80**	0.91	1.33	1.94	1.95	2.50	0.89	1.12
02	1.40	2.20	1.56	1.48	2.67	2.56	**1.37**	8.74
03	3.23	2.04	2.54	2.13	2.07	7.91	**1.49**	3.22
Global Average	3.36	2.60	2.20	**1.89**	2.53	5.06	2.20	8.43

Table 8. Overall translation angle errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for ICL-NUIM `Office` sequences.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	53.37	48.79	19.07	**10.49**	16.38	55.91	32.92	226.99
01	**2.64**	3.23	7.88	13.35	8.33	10.79	3.54	5.81
02	**2.41**	9.05	3.29	2.64	3.69	6.03	2.52	39.93
03	7.51	4.34	5.27	10.85	5.37	19.88	**3.12**	10.07
Global Average	16.48	16.35	8.88	9.34	**8.44**	23.15	10.52	70.70

Table 9. Overall ATE mean in [meters] for ICL-NUIM `Office`.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	0.32	0.36	0.17	**0.10**	0.21	0.41	0.28	0.15
01	0.03	0.03	0.02	**0.01**	0.12	0.06	0.03	0.03
02	**0.04**	0.08	0.06	0.05	0.07	0.08	0.04	0.21
03	0.28	0.20	0.10	**0.03**	0.09	0.75	0.10	0.45
Global Average	0.17	0.17	0.09	**0.05**	0.12	0.32	0.11	0.21

| Rotation Error | Translation Angle Error |
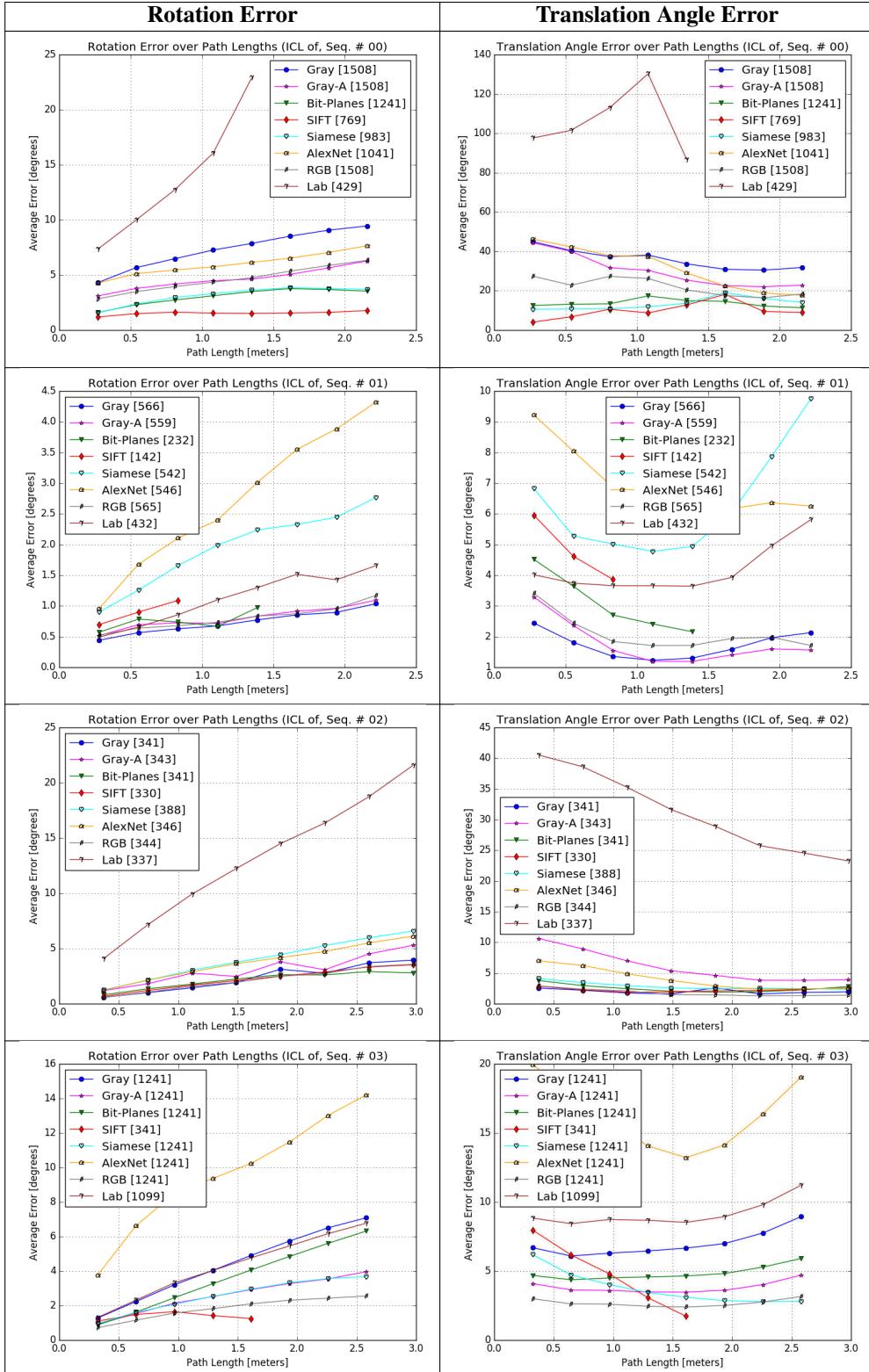
Figure 19. Rotation and translation angle error plots for all ICL Office sequences.

2.4. Complete Numerical Results for the TUM DSO dataset

Table 10. Number of tracked frames for TUM DSO sequences.

Feature	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet
01	1928	971	1174	2708	415	**4757**
02	1521	1524	1775	818	388	**3500**
03	572	**5427**	573	825	2172	**5427**
04	2003	835	1805	**6921**	687	**6921**
05	1511	4761	625	1518	905	**6300**
06	1354	1820	1919	852	788	**4500**
07	2282	**3556**	2168	1885	1669	**3556**
08	1218	929	666	887	893	**2064**
09	**2300**	**2300**	1173	1120	739	**2300**
10	**2100**	**2100**	957	**2100**	468	**2100**
11	**1500**	**1500**	382	192	286	**1500**
12	**2250**	**2250**	645	**2250**	520	**2250**
13	187	196	416	400	136	**1713**
14	566	883	372	531	200	**903**
15	314	303	326	714	225	**2561**
16	1351	1354	**1850**	**1850**	395	**1850**
17	**4980**	**4980**	87	2717	699	**4980**
18	1523	1502	492	3510	754	**6200**
19	**8380**	**8380**	**8380**	3658	194	**8380**
20	2646	4398	**5380**	**5380**	795	**5380**
21	104	4200	4979	**5470**	164	**5470**
22	5056	4999	2999	**5850**	973	1244
23	**3740**	**3740**	**3740**	**3740**	158	**3740**
24	**3500**	**3500**	2630	1282	487	2223
25	995	3398	**4090**	**4090**	1969	**4090**
26	1053	1078	1865	1396	184	**2760**
27	**3480**	**3480**	2185	**3480**	688	**3480**
28	1706	1723	1604	3049	715	**5550**
29	**8400**	**8400**	**8400**	6447	1045	**8400**
30	**1800**	**1800**	**1800**	**1800**	684	**1800**
31	2288	2291	**2310**	1199	1348	2306
32	2318	2120	1587	**2700**	880	**2700**
33	**2760**	**2760**	**2760**	**2760**	1156	**2760**
34	**4290**	**4290**	788	814	1704	1755
35	1242	685	**1623**	1536	1	691
36	999	1061	1084	**1728**	130	334
37	**2970**	**2970**	844	**2970**	178	**2970**
38	163	172	**1249**	1144	312	201
39	520	506	603	**801**	496	521
40	168	1145	654	**3660**	599	1149
41	1552	1506	1246	**2259**	123	1442
42	**4830**	2845	**4830**	1726	214	**4830**
43	979	1007	1113	1343	1560	**1797**
44	**2100**	**2100**	**2100**	**2100**	133	655
45	**3000**	**3000**	2617	1806	147	**3000**
46	**4110**	**4110**	1433	3194	498	**4110**
47	**3260**	**3260**	**3260**	3041	218	**3260**
48	**3250**	**3250**	2942	**3250**	631	**3250**
49	2063	2057	**2841**	1077	442	125
50	**3594**	2766	3408	1517	654	2774
Global Average	2336	2604	2095	2361	636	**3131**

Table 11. Overall rotation errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for TUM DSO sequences.

Feature	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	
01	18.61	19.33	20.05	**13.20**	25.23	15.56	
02	11.67	11.73	11.80	11.48	**11.48**	11.82	
03	21.18	24.81	23.86	18.60	**16.76**	23.09	
04	22.18	21.50	18.44	21.67	**16.71**	21.99	
05	22.01	21.92	30.20	**21.43**	21.88	25.53	
06	11.06	11.45	10.69	11.63	**10.64**	11.90	
07	8.51	10.70	**7.92**	8.46	8.43	10.78	
08	17.81	17.62	18.28	16.89	**13.26**	15.58	
09	10.27	10.40	10.75	**8.81**	8.89	10.42	
10	10.66	10.67	9.69	**8.88**	9.40	10.23	
11	14.36	14.41	12.24	15.28	**9.44**	14.28	
12	13.49	13.41	9.56	11.85	**9.49**	13.45	
13	17.59	17.55	19.00	17.77	**17.09**	17.19	
14	10.70	10.68	10.73	**10.64**	12.05	10.71	
15	18.14	18.13	22.41	**17.55**	18.42	17.63	
16	10.92	10.94	18.66	19.70	**10.76**	19.67	
17	7.40	8.92	135.28	29.38	3.48	**2.56**	
18	7.27	10.65	103.23	18.19	6.62	**3.14**	
19	3.03	4.06	2.64	3.39	44.07	**1.60**	
20	1.98	1.79	2.33	1.42	2.12	**1.40**	
21	48.75	15.73	50.12	10.62	9.66	**2.29**	
22	1.27	1.43	1.39	0.95	5.61	**0.83**	
23	1.73	2.09	1.01	**0.73**	8.38	0.92	
24	**0.83**	0.84	1.87	2.29	2.59	1.74	
25	4.14	3.66	1.95	1.09	1.12	**0.60**	
26	1.01	**0.97**	3.92	1.00	2.74	0.98	
27	0.94	0.81	1.79	1.01	6.65	**0.76**	
28	1.34	1.31	2.77	1.20	1.50	**0.81**	
29	0.99	1.07	1.35	11.43	1.99	**0.80**	
30	0.53	0.81	2.50	0.57	0.91	**0.28**	
31	0.76	0.72	4.58	**0.41**	0.75	0.58	
32	1.60	1.77	1.26	7.79	1.44	**0.38**	
33	0.29	**0.27**	0.41	0.47	0.69	0.31	
34	0.80	0.86	1.22	**0.55**	1.62	0.58	
35	1.49	1.22	3.38	2.08	nan	**0.53**	
36	1.17	3.55	6.28	3.80	3.81	**1.07**	
37	0.67	1.01	2.57	**0.50**	1.55	1.12	
38	2.34	1.67	5.21	2.07	1.33	**1.00**	
39	1.88	1.80	4.65	2.34	1.37	**0.83**	
40	5.77	**1.72**	15.56	2.27	2.27	1.72	
41	2.67	2.53	0.92	**0.76**	8.13	2.52	
42	0.40	0.47	0.54	0.40	1.12	**0.26**	
43	1.02	1.41	**0.20**	0.49	0.75	0.27	
44	0.17	0.12	**0.11**	0.57	nan	0.36	
45	2.25	2.51	7.38	1.42	12.33	**1.39**	
46	3.75	3.63	3.65	14.39	**2.68**	3.54	
47	2.94	2.89	11.70	35.42	5.09	**2.71**	
48	**2.35**	6.96	4.10	4.44	7.08	2.49	
49	**5.76**	18.06	39.06	7.00	7.81	8.28	
50	13.77	12.80	7.04	**4.43**	11.76	8.57	
Global Average	7.44	7.31	13.73	8.17	8.10	**6.14**	

Table 12. Overall translation angle errors in $\left[\frac{degree}{meter}\right]$ for TUM DSO sequences.

Feature	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	
01	**28.04**	28.41	33.58	31.09	52.19	29.78	
02	29.77	29.73	29.70	30.31	29.82	**28.00**	
03	29.65	**25.11**	36.75	27.48	26.62	27.08	
04	46.05	**44.76**	49.50	47.74	49.29	48.33	
05	54.95	55.15	61.92	55.23	**54.62**	62.52	
06	23.95	**23.94**	24.41	25.36	24.51	25.47	
07	15.77	17.79	16.69	**15.63**	15.69	17.72	
08	35.98	35.73	32.76	32.94	32.38	**30.08**	
09	**20.51**	20.83	20.82	22.40	22.12	20.98	
10	15.82	15.80	**15.19**	15.23	15.80	16.08	
11	21.89	21.73	21.59	25.28	**20.37**	22.08	
12	**30.32**	30.56	30.84	31.29	31.55	30.71	
13	45.33	45.41	45.15	45.46	45.93	**43.89**	
14	**22.73**	22.74	22.83	22.92	28.84	22.88	
15	33.27	33.32	**30.65**	33.88	34.41	36.36	
16	27.17	27.31	**23.20**	23.81	28.26	23.88	
17	12.48	16.56	442.23	101.26	4.28	**2.98**	
18	8.97	13.20	212.91	25.57	8.67	**3.55**	
19	6.47	8.76	7.72	7.33	199.10	**4.25**	
20	2.41	2.63	3.24	1.68	3.19	**1.62**	
21	221.66	77.09	125.09	49.82	13.97	**12.20**	
22	3.20	3.40	3.88	2.21	15.08	**1.74**	
23	3.72	4.33	2.94	**2.20**	22.52	2.79	
24	5.27	3.74	7.23	7.52	4.40	**2.25**	
25	8.58	7.90	3.05	2.42	2.06	**1.49**	
26	**2.41**	2.43	9.80	2.72	6.93	3.87	
27	1.71	3.87	4.60	2.93	16.43	**1.70**	
28	3.33	3.14	17.73	2.32	2.68	**1.72**	
29	1.43	1.53	1.21	21.79	3.62	**0.98**	
30	1.03	1.61	7.23	1.04	1.91	**0.58**	
31	2.46	2.38	21.80	**1.50**	1.98	2.15	
32	3.11	3.29	2.34	33.21	2.71	**0.68**	
33	0.66	**0.57**	0.77	1.00	1.67	0.66	
34	1.65	1.79	3.27	1.88	5.73	**1.60**	
35	3.37	3.06	11.05	4.85	nan	**1.12**	
36	**2.21**	7.15	12.69	7.78	10.20	2.56	
37	2.61	4.61	13.17	**1.51**	5.04	6.72	
38	7.65	4.39	18.29	6.33	4.18	**2.08**	
39	5.01	5.15	12.17	5.36	3.45	**2.05**	
40	13.64	3.61	58.53	4.87	3.93	**3.23**	
41	6.41	6.31	2.25	**2.22**	21.13	6.26	
42	1.00	1.13	1.19	0.96	3.87	**0.74**	
43	5.11	4.36	**0.67**	1.36	3.39	0.76	
44	0.51	0.39	**0.33**	1.44	nan	0.79	
45	4.82	5.90	35.95	4.12	31.49	**3.71**	
46	12.91	12.72	11.55	58.17	**10.52**	25.78	
47	13.35	12.07	47.19	169.52	19.97	**9.56**	
48	**7.33**	16.03	47.28	30.75	24.88	7.88	
49	16.00	54.68	239.63	27.54	**14.39**	23.11	
50	28.73	24.90	16.47	**11.73**	17.59	17.41	
Global Average	18.05	16.06	38.02	21.86	20.90	**12.93**	

Table 13. Mean absolute trajectory error (ATE) in meters for TUM DSO sequences.

Feature	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	
01	1.11	1.49	2.13	**0.13**	0.22	2.03	
02	0.30	0.30	0.64	0.20	**0.09**	1.91	
03	0.32	1.45	1.06	0.81	**0.17**	1.85	
04	0.61	1.12	0.37	1.37	**0.05**	1.35	
05	0.05	0.04	0.65	0.05	**0.04**	1.14	
06	0.23	0.41	0.16	0.81	**0.14**	2.13	
07	0.19	2.14	0.59	**0.08**	0.12	2.09	
08	1.45	1.16	1.11	1.07	**0.26**	1.00	
09	1.96	1.90	1.63	**0.12**	0.15	1.50	
10	2.99	3.13	2.14	3.58	**0.16**	3.60	
11	1.71	2.12	1.60	1.25	**0.15**	1.85	
12	1.28	1.23	0.20	1.86	**0.07**	1.21	
13	0.03	**0.02**	0.32	0.11	0.04	1.55	
14	0.19	0.14	0.26	0.15	0.12	**0.09**	
15	0.07	0.07	1.23	0.07	**0.06**	1.50	
16	0.84	**0.44**	1.82	1.49	0.66	1.69	
17	0.12	0.12	0.07	0.08	**0.00**	0.12	
18	0.01	0.01	0.09	0.02	**0.01**	0.11	
19	0.16	0.16	0.16	**0.02**	0.03	0.16	
20	0.04	**0.03**	0.35	0.35	0.04	0.30	
21	0.06	0.07	0.12	0.16	**0.03**	0.16	
22	0.00	0.00	0.00	0.00	0.01	**0.00**	
23	0.41	0.41	0.42	0.41	**0.01**	0.41	
24	0.79	0.79	0.16	0.12	0.10	**0.08**	
25	0.07	0.07	0.57	0.56	**0.02**	0.58	
26	0.03	**0.03**	0.14	0.03	0.04	0.50	
27	0.22	0.22	**0.01**	0.22	0.04	0.22	
28	0.03	0.03	0.15	0.03	**0.02**	0.25	
29	0.17	0.14	0.17	0.06	**0.01**	0.17	
30	0.41	0.46	0.49	0.51	**0.03**	0.49	
31	0.03	0.03	0.19	**0.02**	0.02	0.02	
32	0.03	0.03	**0.03**	0.38	0.04	0.38	
33	0.57	0.57	0.57	0.57	**0.06**	0.58	
34	0.17	0.17	0.01	0.00	0.01	**0.00**	
35	0.10	0.10	0.28	0.13	**0.00**	0.04	
36	0.08	0.36	0.56	0.32	**0.05**	0.05	
37	0.70	0.69	0.35	0.69	**0.04**	0.50	
38	0.04	0.03	0.31	0.08	0.03	**0.02**	
39	0.04	0.04	0.08	0.05	0.03	**0.02**	
40	0.02	0.01	0.15	0.02	0.01	**0.01**	
41	0.02	0.02	0.01	**0.01**	0.02	0.01	
42	0.18	**0.00**	0.18	0.00	0.00	0.18	
43	0.07	0.05	**0.01**	0.02	0.03	0.01	
44	0.67	0.67	0.66	0.50	**0.01**	0.02	
45	0.12	0.12	0.13	**0.01**	0.05	0.12	
46	0.19	0.19	0.03	0.07	**0.02**	0.19	
47	0.06	0.06	0.06	0.06	**0.01**	0.06	
48	0.08	0.08	0.03	0.08	**0.01**	0.08	
49	**0.00**	0.01	0.04	0.00	0.00	0.00	
50	0.04	0.03	0.03	**0.02**	0.02	0.02	
Global Average	0.38	0.46	0.45	0.37	**0.07**	0.65	

Rotation Error	Translation Angle Error
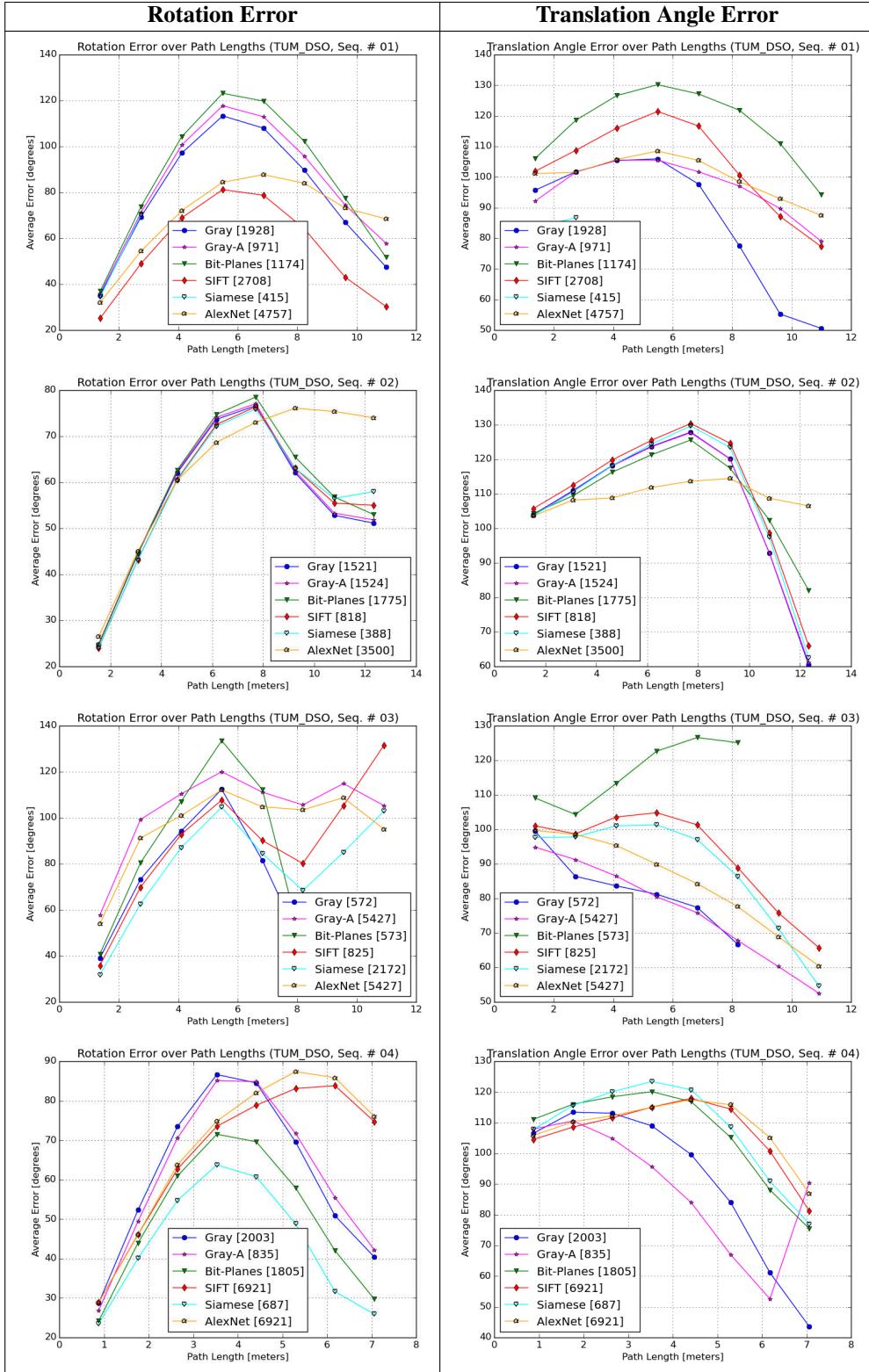
Figure 20. Rotation and translation angle error plots for DSO sequences (1-4).

| Rotation Error | Translation Angle Error |
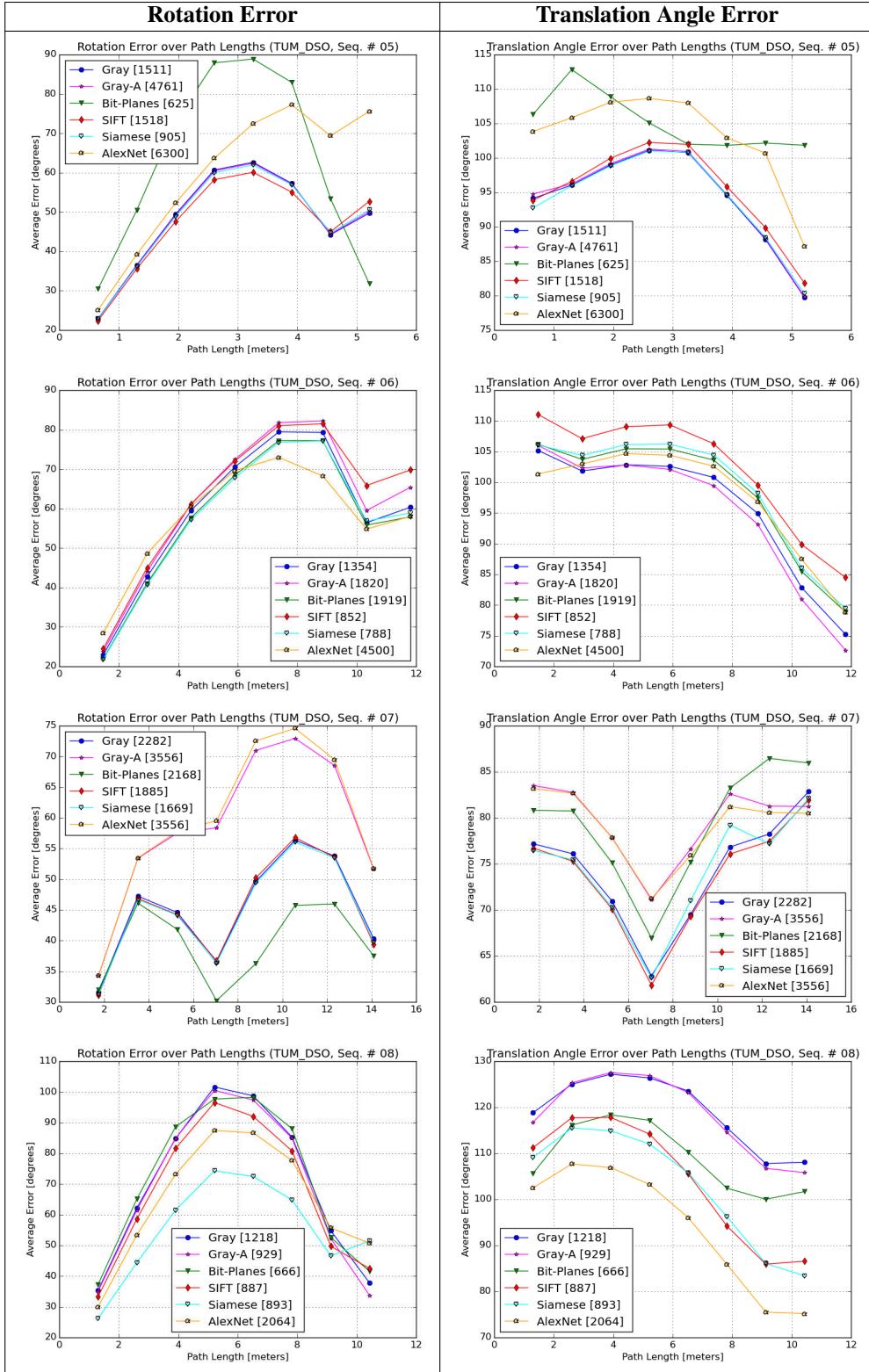
Figure 21. Rotation and translation angle error plots for DSO sequences (5-8).
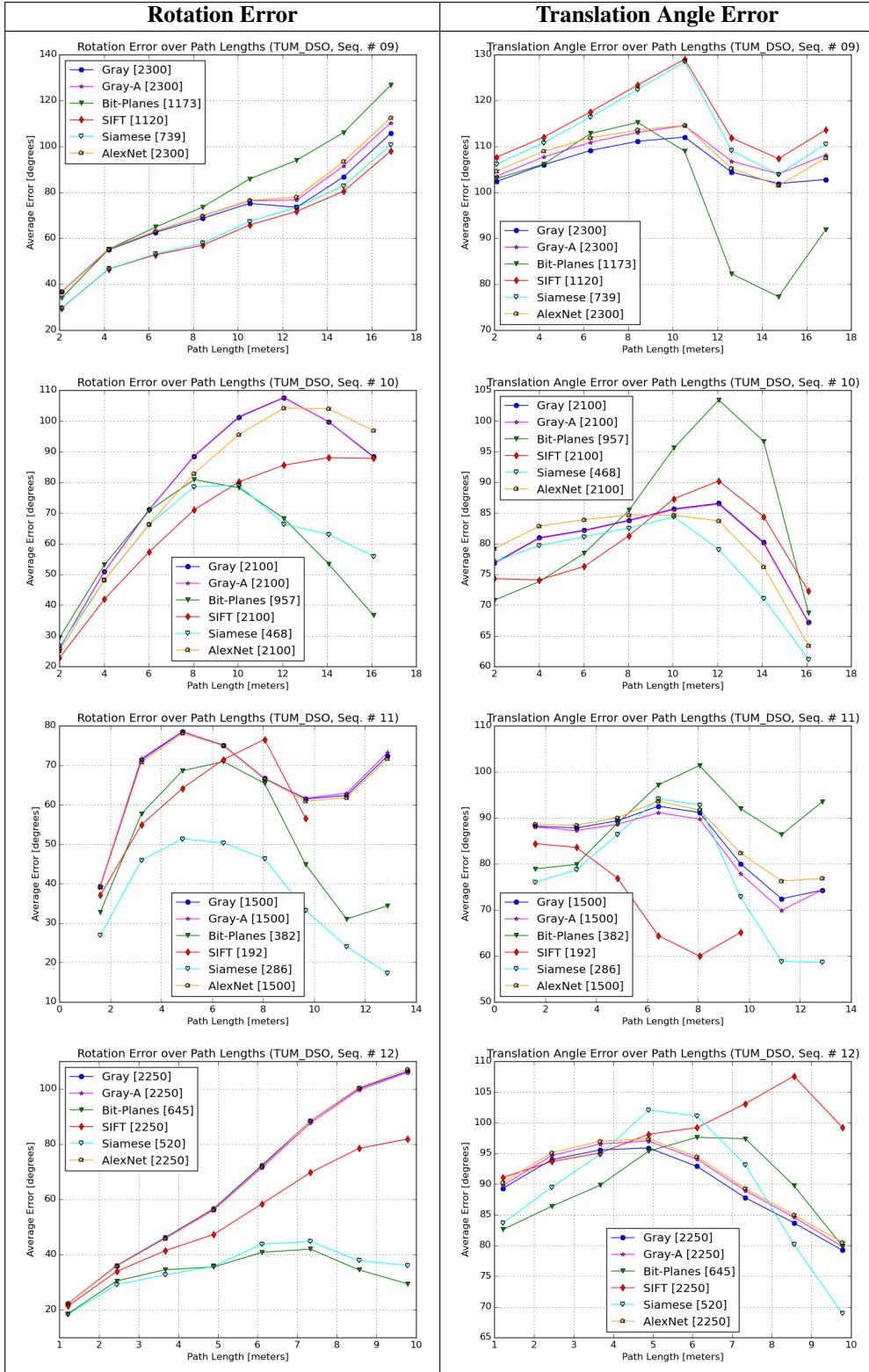
Figure 22. Rotation and translation angle error plots for DSO sequences (9-12).

Rotation Error

Translation Angle Error
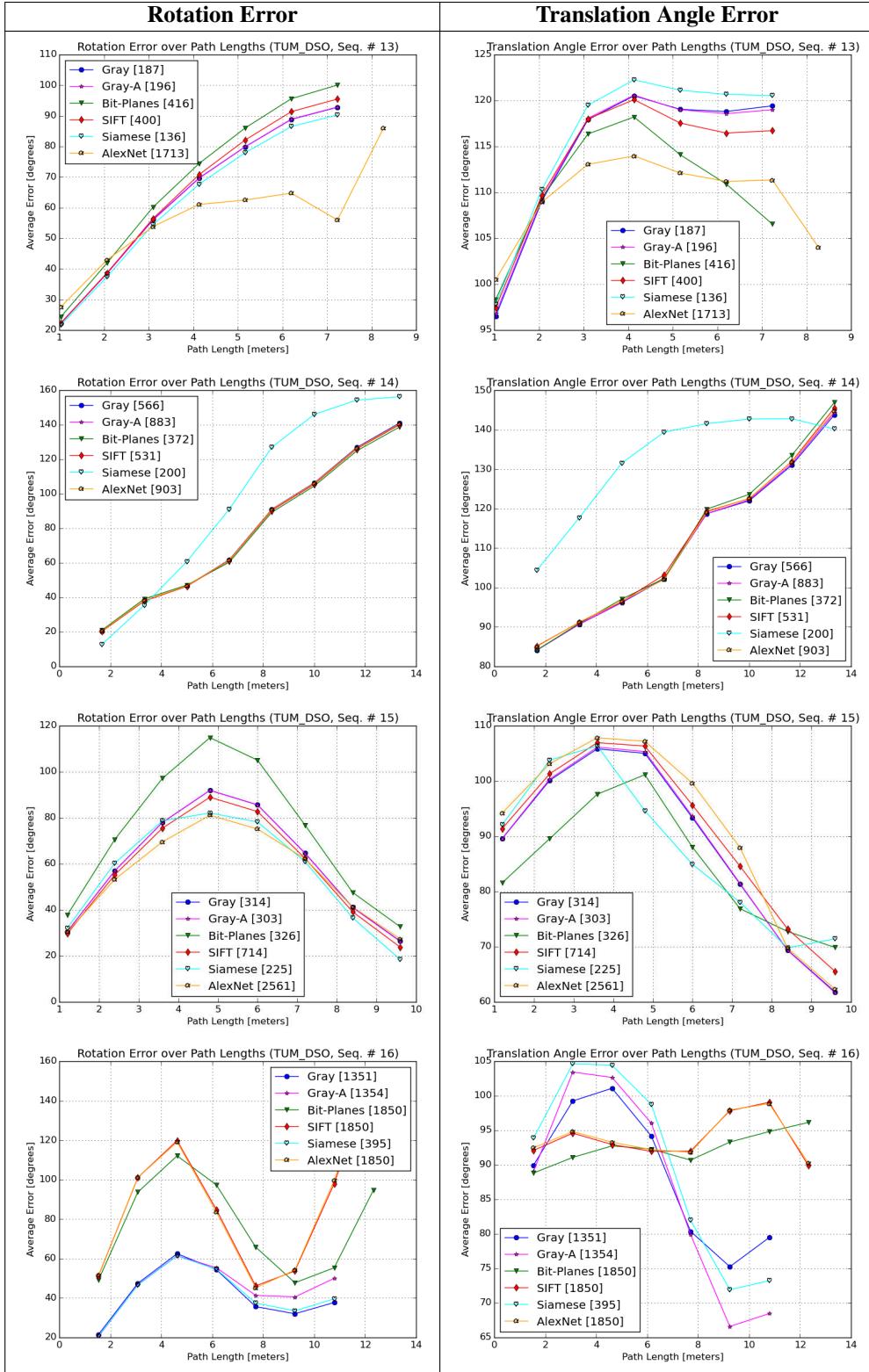
Figure 23. Rotation and translation angle error plots for DSO sequences (13-16).
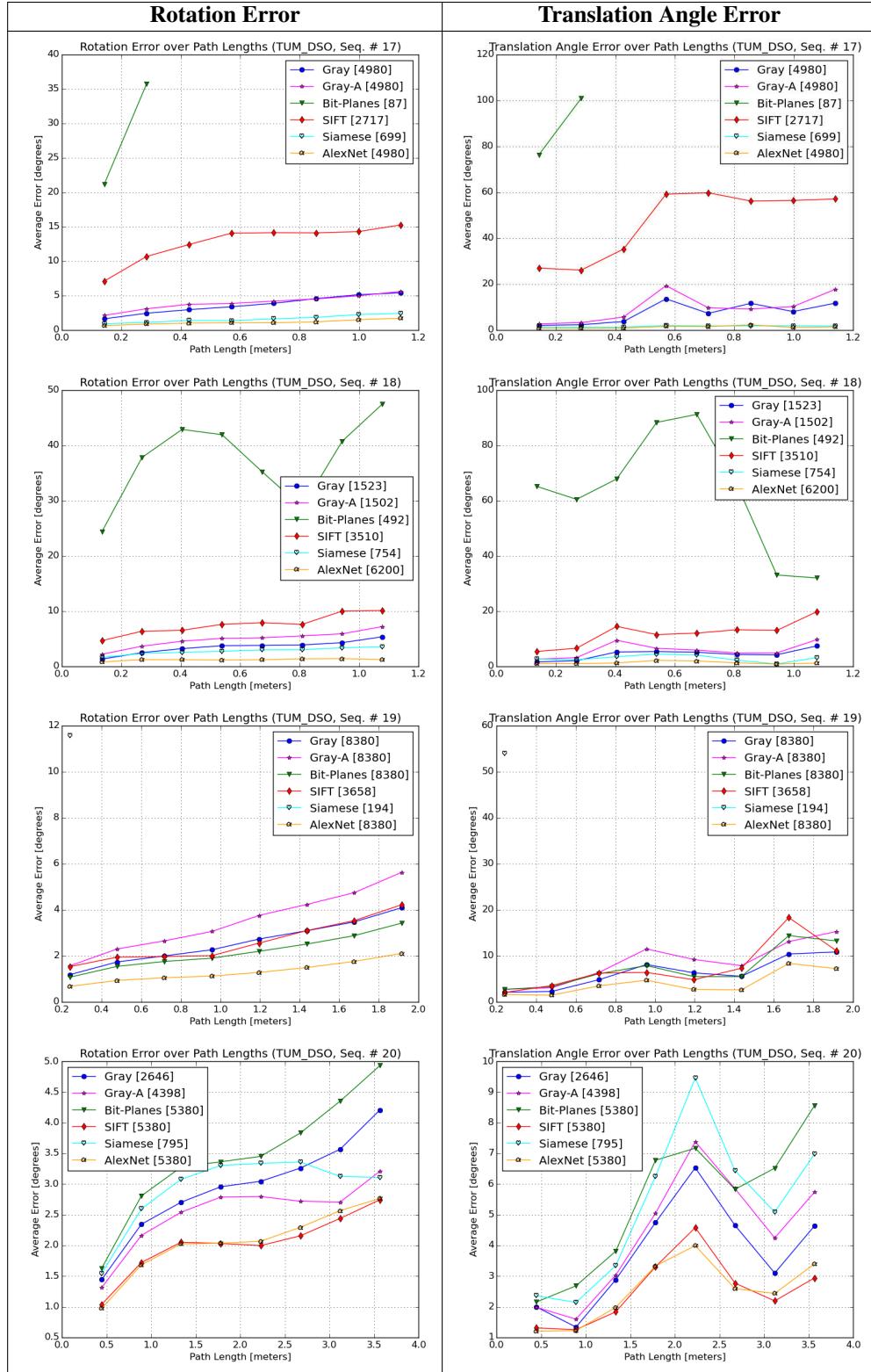
Figure 24. Rotation and translation angle error plots for DSO sequences (17-20).

Rotation Error | **Translation Angle Error**
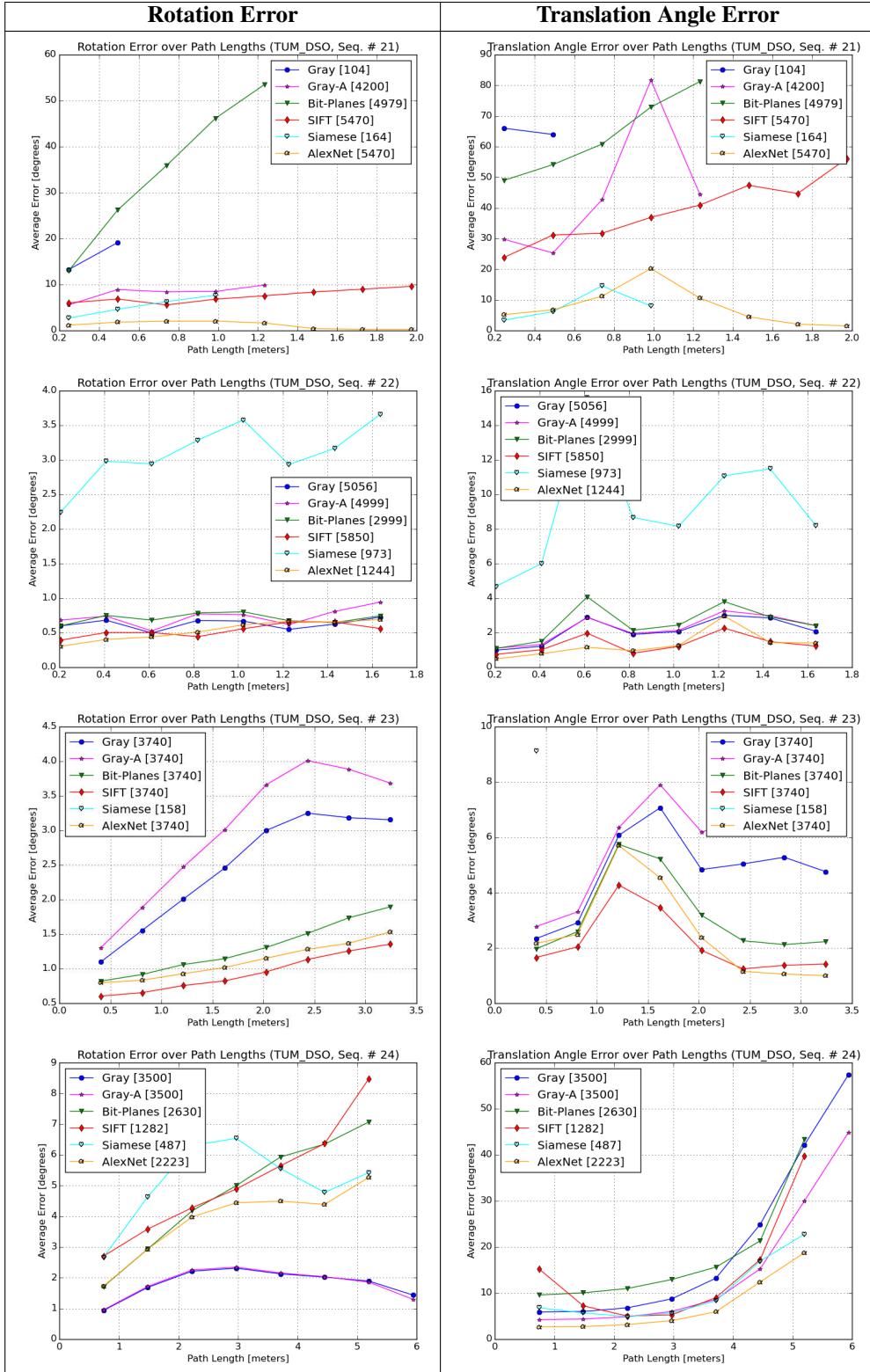
Figure 25. Rotation and translation angle error plots for DSO sequences (21-24).
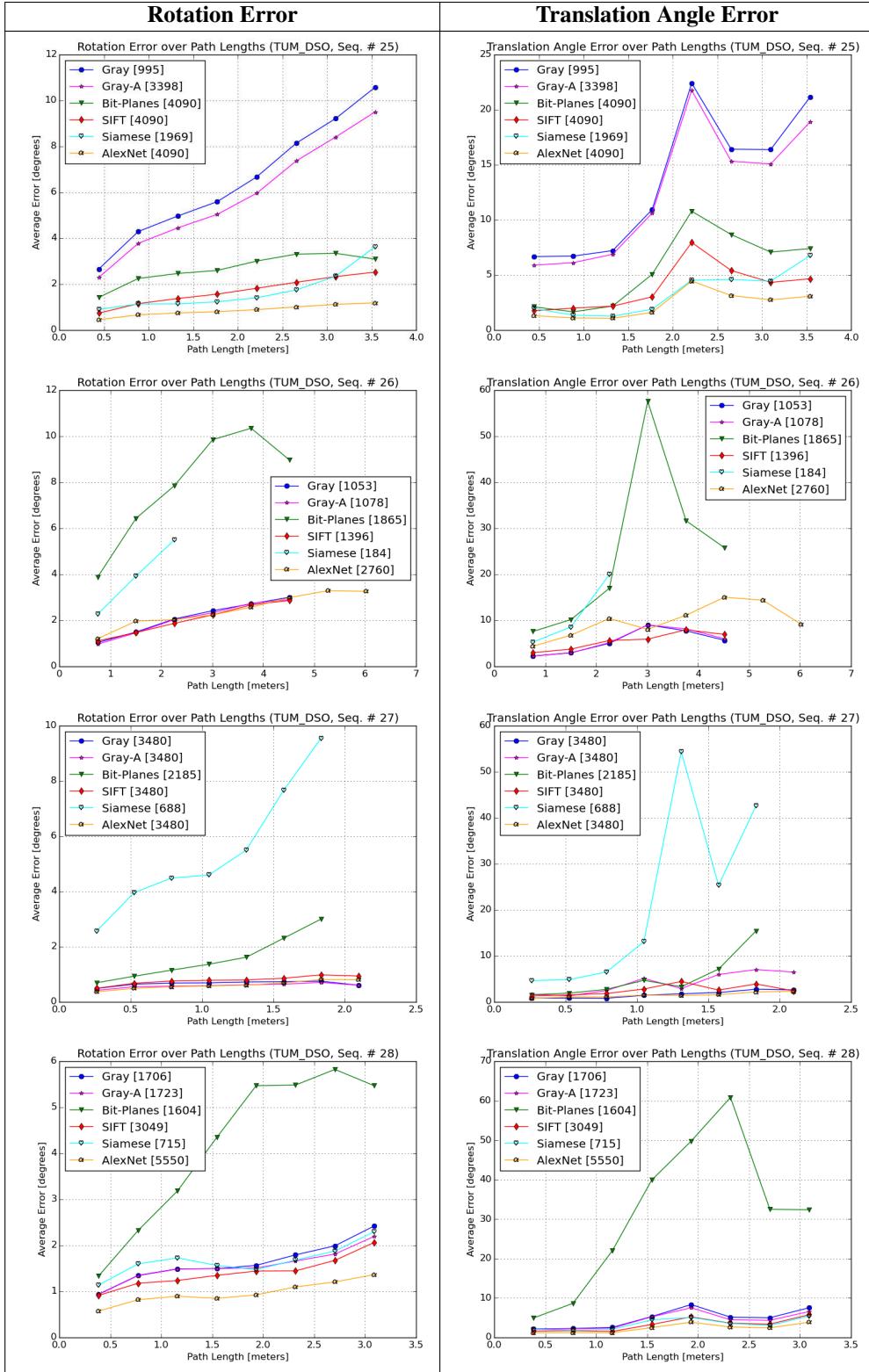
Figure 26. Rotation and translation angle error plots for DSO sequences (25-28).

Rotation Error	Translation Angle Error
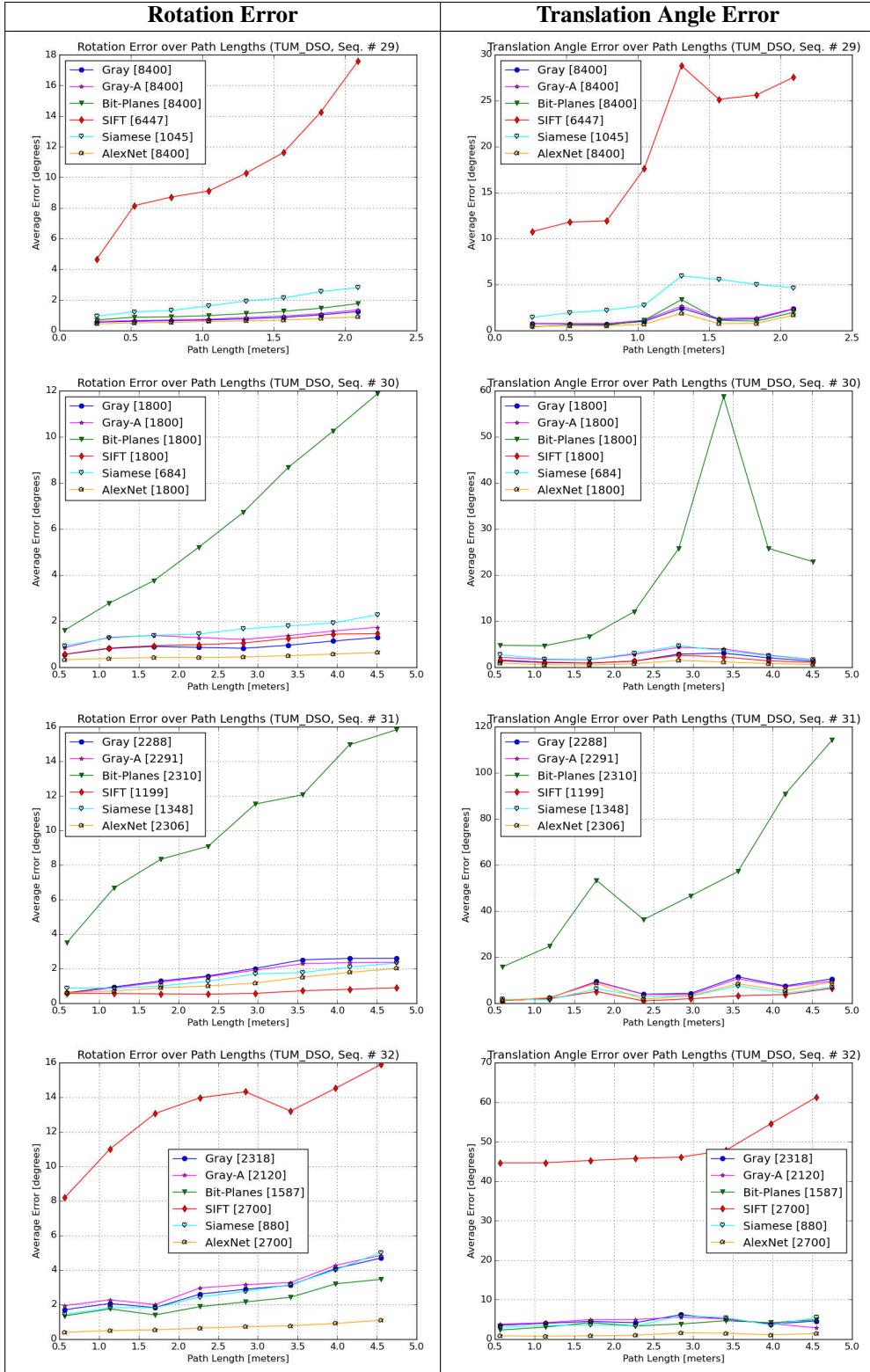
Figure 27. Rotation and translation angle error plots for DSO sequences (29-32).

Rotation Error   **Translation Angle Error**
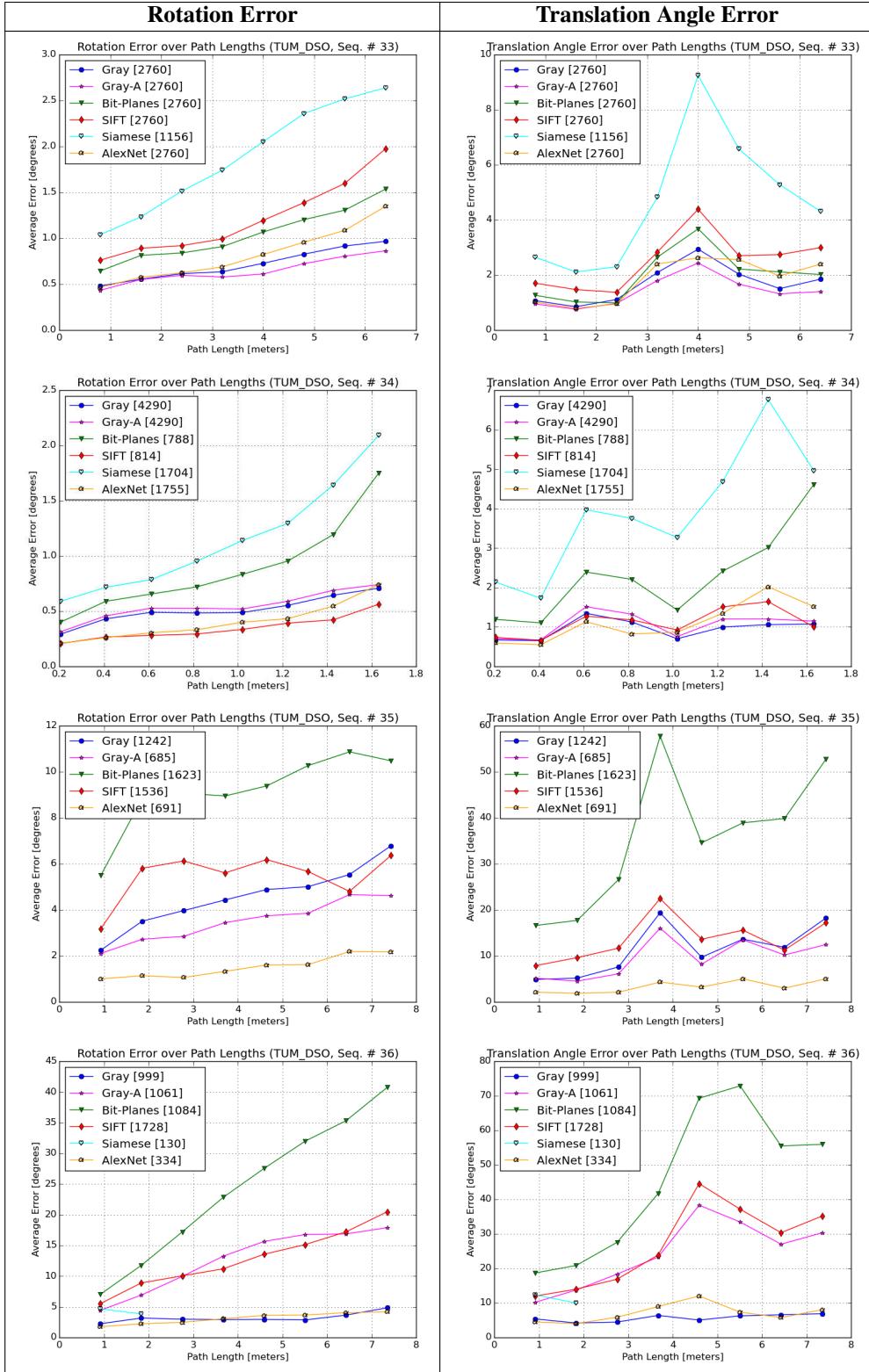
Figure 28. Rotation and translation angle error plots for DSO sequences (33-36).

Rotation Error	Translation Angle Error
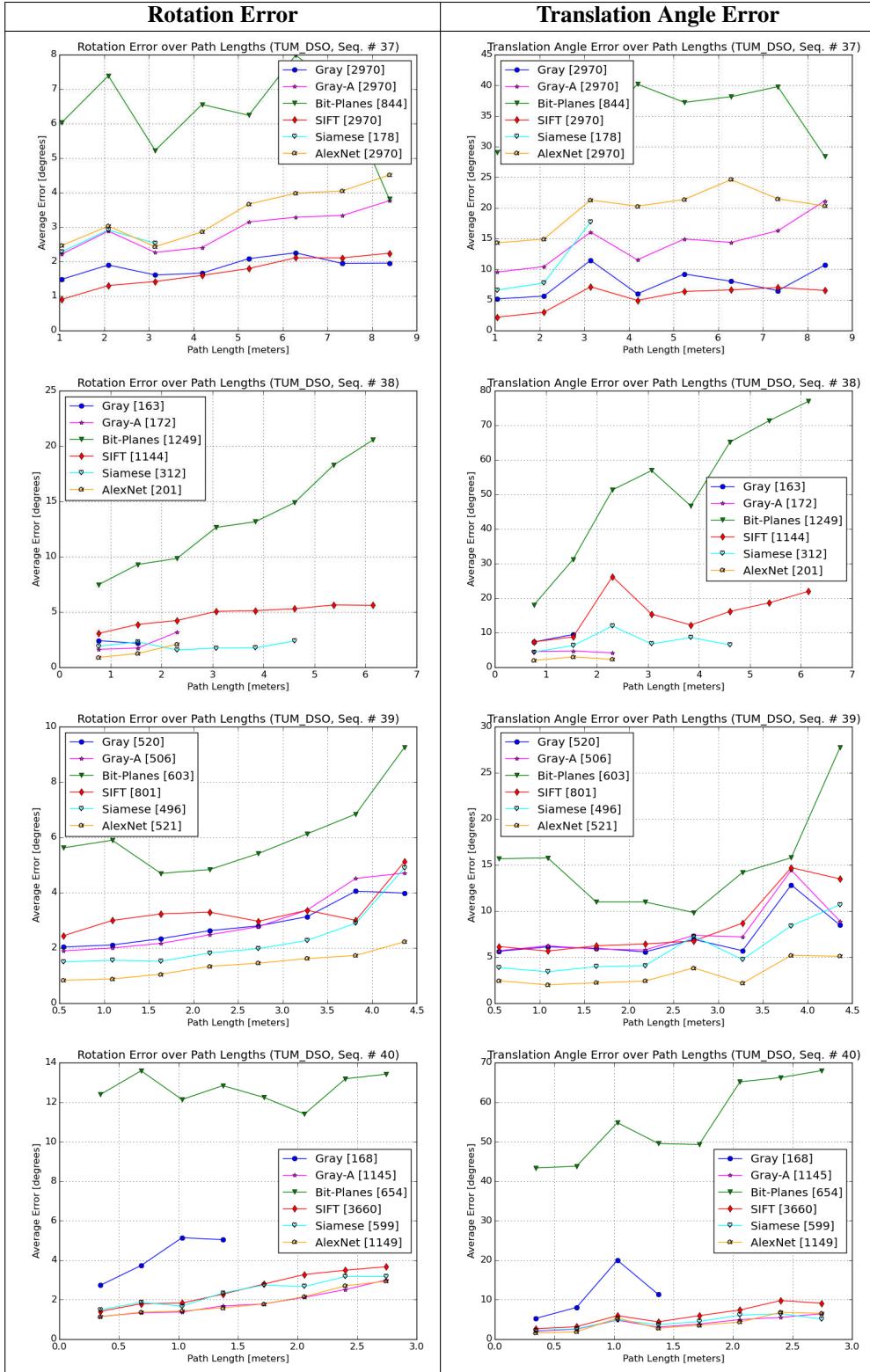
Figure 29. Rotation and translation angle error plots for DSO sequences (37-40).

| Rotation Error | Translation Angle Error |
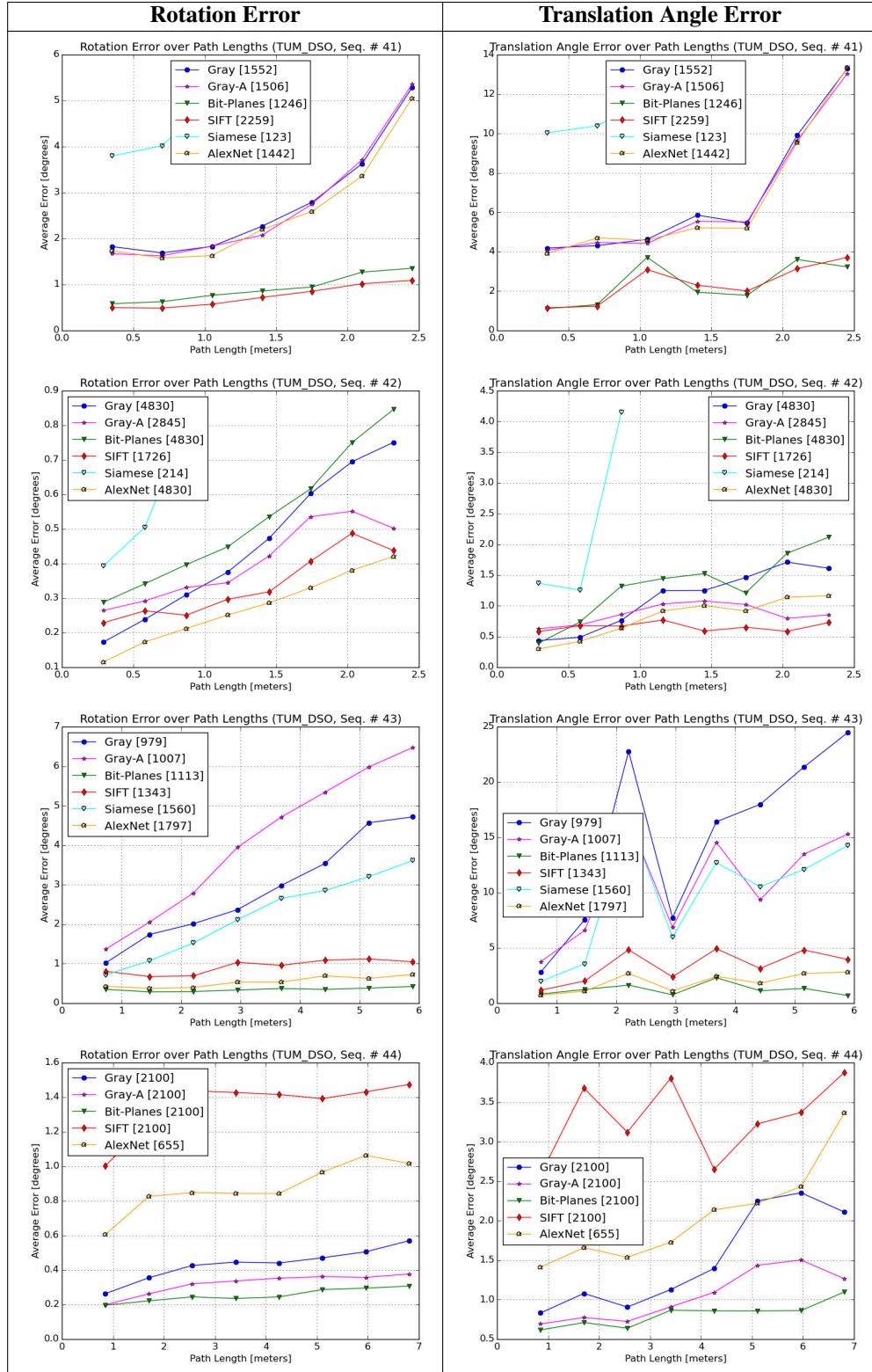
Figure 30. Rotation and translation angle error plots for DSO sequences (41-44).
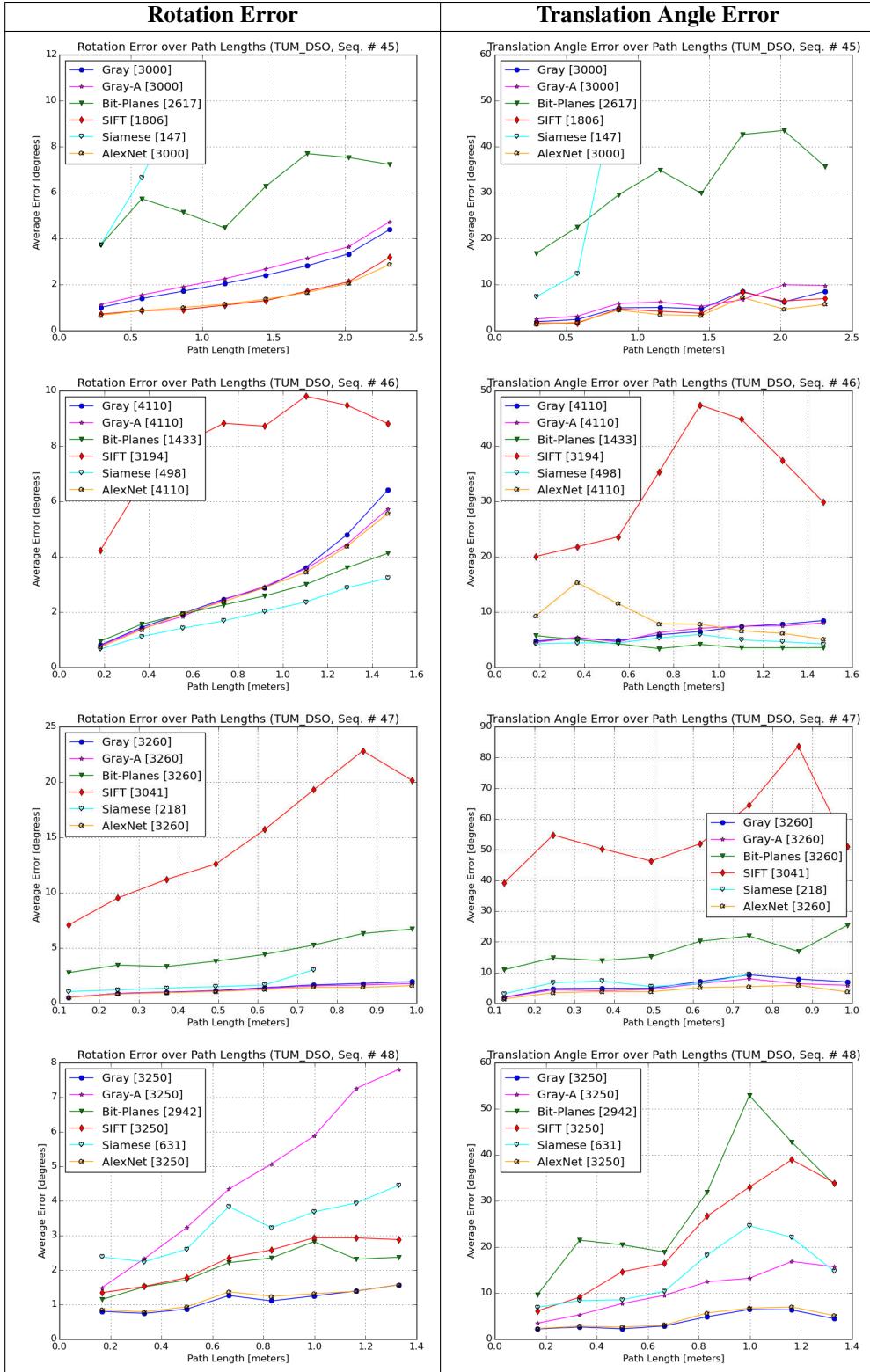
Figure 31. Rotation and translation angle error plots for DSO sequences (45-48).
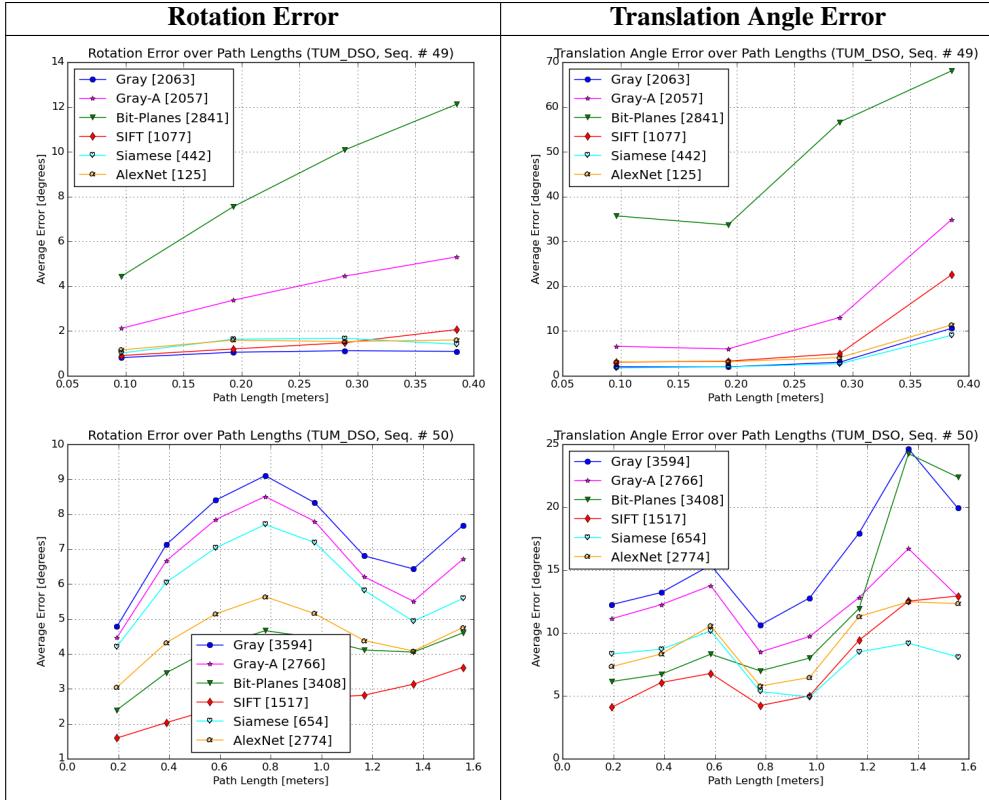
Figure 32. Rotation and translation angle error plots for DSO sequences (49-50).

2.5. Complete Numerical Results for the KITTI dataset
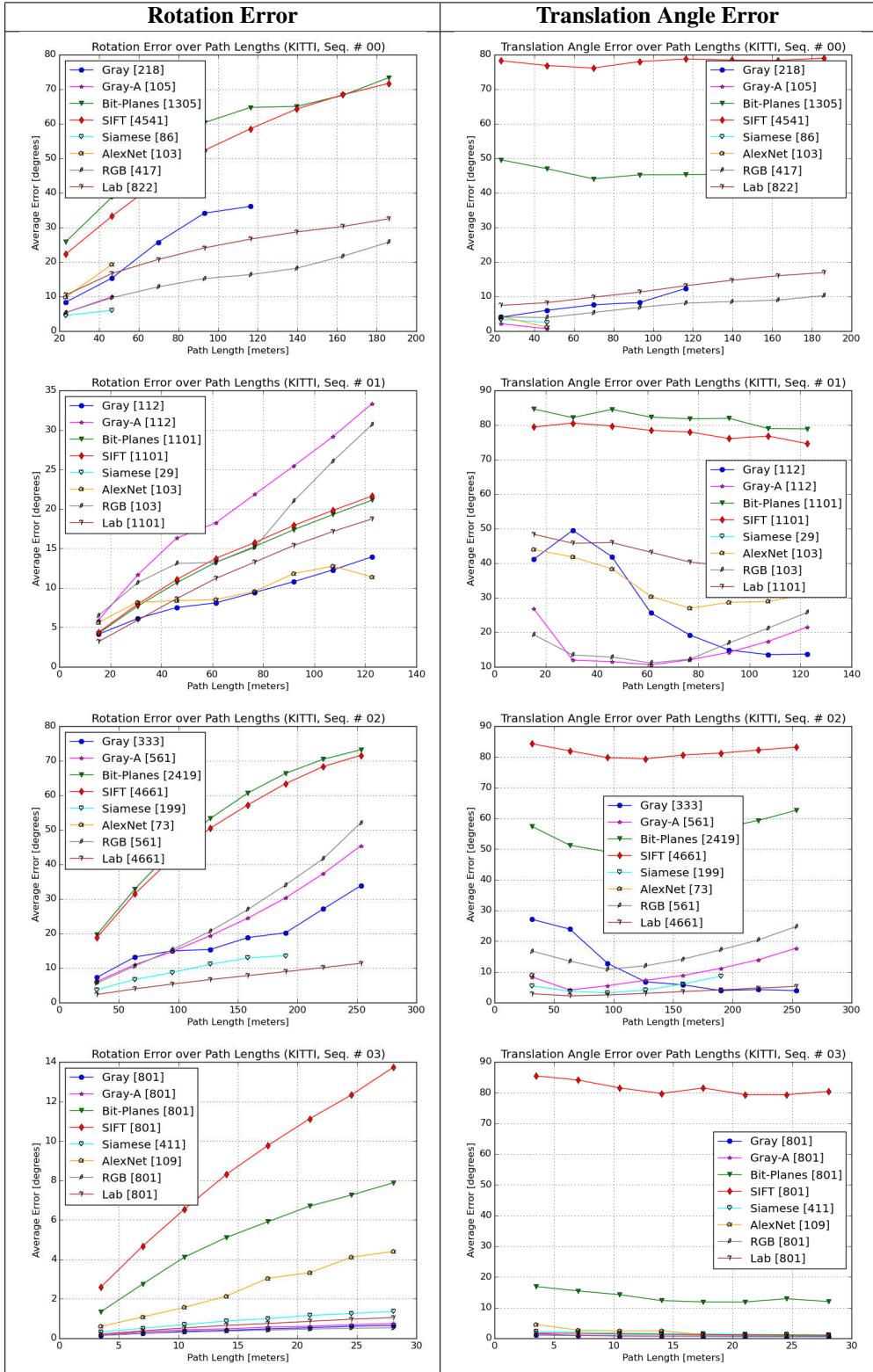

Figure 33. Rotation and translation angle error plots for DSO sequences (0-3).
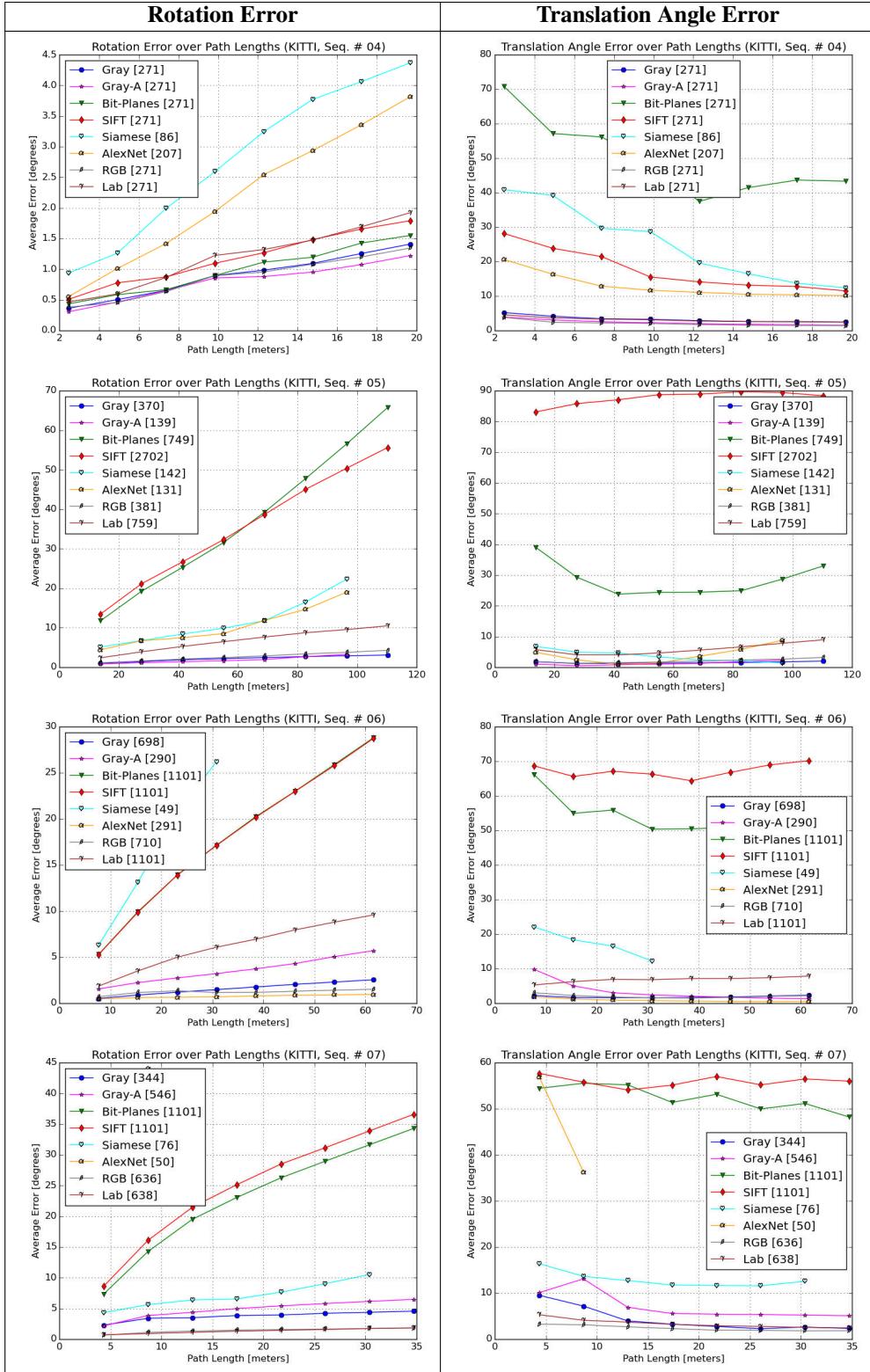
Figure 34. Rotation and translation angle error plots for DSO sequences (4-7).

Rotation Error	Translation Angle Error
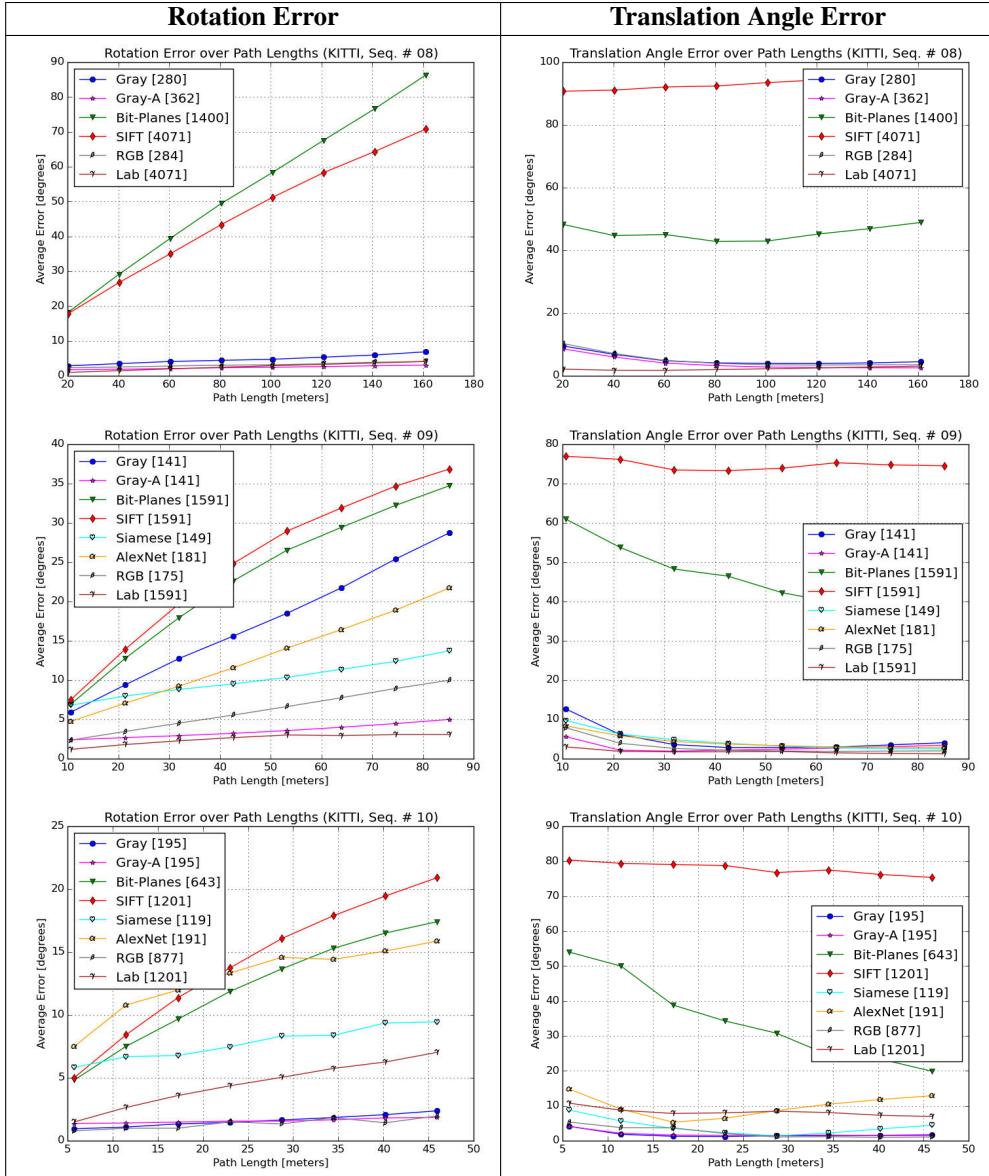
Figure 35. Rotation and translation angle error plots for DSO sequences (8-10).

Table 14. Number of tracked frames for KITTI sequences.

Sequence / Feature	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	218	105	1305	**4541**	86	103	417	822
01	112	112	**1101**	**1101**	29	103	103	**1101**
02	333	561	2419	**4661**	199	73	561	**4661**
03	**801**	**801**	**801**	**801**	411	109	**801**	**801**
04	**271**	**271**	**271**	**271**	86	207	**271**	**271**
05	370	139	749	**2702**	142	131	381	759
06	698	290	**1101**	**1101**	49	291	710	**1101**
07	344	546	**1101**	**1101**	76	50	636	638
08	280	362	1400	**4071**	67	62	284	**4071**
09	141	141	**1591**	**1591**	149	181	175	**1591**
10	195	195	643	**1201**	119	191	877	**1201**
Global Average	342	320	1135	**2104**	128	136	474	1547

Table 15. Overall rotation errors in $\left[\frac{degree}{meter}\right]$ for KITTI sequences.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	0.35	0.22	0.66	0.58	**0.17**	0.42	0.17	0.28
01	**0.16**	0.32	0.21	0.22	2.66	0.20	0.29	0.18
02	0.16	0.17	0.42	0.40	0.10	0.20	0.18	**0.05**
03	0.03	0.04	0.35	0.59	0.06	0.16	**0.03**	0.05
04	0.09	**0.08**	0.10	0.12	0.27	0.20	0.09	0.12
05	0.04	**0.04**	0.64	0.64	0.24	0.22	0.05	0.12
06	0.05	0.12	0.56	0.56	0.85	**0.03**	0.05	0.19
07	0.26	0.31	1.32	1.46	0.56	5.02	0.09	**0.08**
08	0.07	0.04	0.64	0.57	nan	nan	0.05	**0.03**
09	0.40	0.11	0.52	0.56	0.30	0.30	0.15	**0.06**
10	0.08	0.09	0.54	0.61	0.44	0.67	**0.07**	0.19
Global Average	0.16	0.14	0.54	0.58	0.57	0.74	**0.11**	0.12

Table 16. Overall translation angle errors in $\left[\frac{degree}{meter}\right]$ for KITTI sequences.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	0.13	**0.06**	0.72	1.15	0.10	0.10	0.09	0.15
01	0.95	0.48	1.87	1.78	2.27	1.06	**0.44**	1.01
02	0.25	0.09	0.59	0.89	0.08	0.23	0.18	**0.03**
03	**0.09**	0.11	1.46	8.21	0.19	0.38	0.09	0.15
04	0.56	0.41	7.99	3.04	4.69	2.20	**0.37**	0.51
05	0.04	**0.03**	0.80	2.14	0.18	0.12	0.05	0.14
06	0.09	0.27	2.59	3.02	1.22	**0.06**	0.10	0.28
07	0.53	0.70	4.29	4.50	1.43	7.68	**0.22**	0.33
08	0.14	0.11	0.81	1.57	nan	nan	0.14	**0.04**
09	0.29	0.14	1.69	2.44	0.24	0.21	0.17	**0.07**
10	**0.16**	0.16	2.61	4.73	0.38	0.69	0.21	0.54
Global Average	0.29	0.23	2.31	3.04	1.08	1.27	**0.19**	0.29

Table 17. Mean absolute trajectory error (ATE) in meters for KITTI sequences.

Feature Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
00	7.34	**4.16**	84.44	170.97	8.41	6.43	10.79	58.90
01	17.33	11.87	463.32	491.70	**3.31**	14.80	4.54	422.75
02	15.69	41.10	170.91	235.07	8.48	**3.50**	45.25	105.44
03	2.28	1.52	18.40	144.20	3.63	**0.67**	3.82	13.25
04	20.12	13.46	44.25	34.74	15.00	32.57	19.91	**12.68**
05	1.87	**0.36**	47.42	138.74	12.64	4.48	4.77	40.72
06	29.30	19.54	117.07	114.49	3.38	**1.35**	21.37	111.73
07	1.95	14.52	75.67	83.39	**0.83**	2.41	5.80	7.68
08	3.20	2.12	77.37	164.80	**0.74**	0.80	1.99	64.18
09	6.63	**2.17**	182.65	192.38	12.36	13.30	2.44	22.78
10	1.85	**0.78**	92.85	91.83	9.74	4.98	14.47	52.31
Global Average	9.78	10.15	124.94	169.30	**7.14**	7.75	12.29	82.95

2.6. Complete Numerical Results for the Tsukuba dataset

Table 18. Number of tracked frames for Tsukuba sequences.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
daylight	665	666	905	**1530**	349	510	665	663
flashlight	229	224	823	**1800**	237	240	227	197
fluorescent	1118	1121	904	1078	315	510	**1124**	**1124**
lamps	170	166	476	**1800**	124	140	163	120
Global Average	546	544	777	**1552**	256	350	545	526

Table 19. Overall rotation errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for Tsukuba sequences.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
daylight	9.42	11.16	**7.07**	19.02	9.64	12.34	9.81	9.59
flashlight	29.66	35.16	**22.09**	27.50	33.42	34.92	25.20	33.78
fluorescent	**8.63**	9.42	9.46	13.77	18.62	10.99	9.06	9.06
lamps	92.96	90.69	**16.41**	21.47	75.40	90.62	84.02	40.79
Global Average	35.17	36.61	**13.76**	20.44	34.27	37.22	32.02	23.31

Table 20. Overall translation angle errors in $\left[\frac{\text{degree}}{\text{meter}}\right]$ for Tsukuba.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
daylight	20.71	23.02	19.23	52.30	20.87	**13.87**	18.43	17.27
flashlight	41.51	47.62	50.14	60.92	49.90	**35.71**	40.72	83.67
fluorescent	21.43	21.02	27.54	41.32	46.42	23.39	**18.51**	23.72
lamps	113.52	108.46	**47.81**	62.88	157.25	150.04	117.33	68.42
Global Average	49.29	50.03	**36.18**	54.36	68.61	55.75	48.75	48.27

Table 21. Overall ATE mean in [meters] for Tsukuba.

Feature / Sequence	Gray	Gray-A	Bit-Planes	SIFT	Siamese	AlexNet	RGB	Lab
daylight	0.63	0.55	1.66	2.95	**0.24**	0.41	0.50	0.46
flashlight	0.13	**0.12**	1.38	3.17	0.14	0.16	0.16	0.19
fluorescent	1.50	1.61	1.66	2.19	**0.44**	0.51	1.70	1.41
lamps	0.03	0.02	0.80	3.08	**0.02**	0.02	0.02	0.03
Global Average	0.57	0.58	1.37	2.85	**0.21**	0.28	0.59	0.52

| Rotation Error	Translation Angle Error
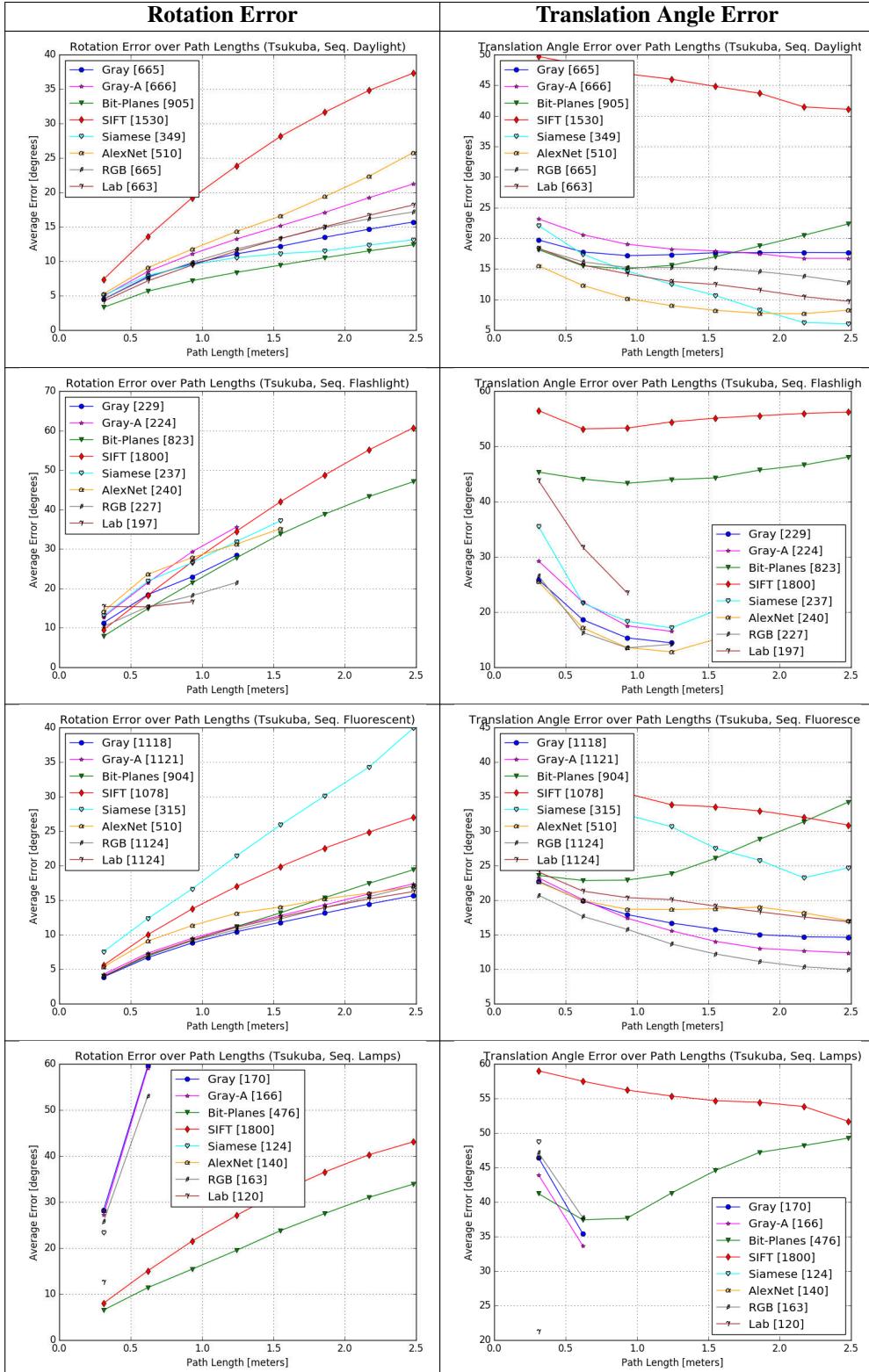
Figure 36. Rotation and translation angle error plots for the Tsukuba dataset.

2.7. Final Rankings (Standard Competition)

Feature	Tracked Frames Wins Count	Tracked Frames Average Ranking	Rotation Error Wins Count	Rotation Error Average Ranking	Trans. Ang. Error Wins Count	Trans. Ang. Error Average Ranking	ATE Wins Count	ATE Average Ranking
Gray	21	2.76	3	3.58	7	3.24	1	3.92
Gray-A	21	2.60	3	3.62	4	3.40	5	3.80
Bit-Planes	15	3.18	3	4.40	5	4.14	3	4.16
SIFT	20	2.82	12	3.18	6	3.72	8	3.42
Siamese	0	5.54	10	3.72	4	4.06	**26**	**1.88**
AlexNet	**37**	**1.74**	**19**	**2.50**	**24**	**2.44**	7	3.82

Table 22. Experimental rankings for the TUM DSO dataset.

Feature	Tracked Frames Wins Count	Tracked Frames Average Ranking	Rotation Error Wins Count	Rotation Error Average Ranking	Trans. Ang. Error Wins Count	Trans. Ang. Error Average Ranking	ATE Wins Count	ATE Average Ranking
Gray	2	4.64	1	3.09	2	3.27	0	3.45
Gray-A	2	4.64	2	3.09	2	**2.36**	**4**	**2.55**
Bit-Planes	6	1.91	0	6.36	0	6.82	0	7.27
SIFT	**11**	**1.00**	0	6.73	0	7.36	0	7.73
Siamese	0	7.27	1	5.36	0	5.27	3	2.82
AlexNet	0	7.00	1	5.73	1	5.09	3	2.82
RGB	2	3.73	2	**2.73**	**3**	2.45	0	3.91
Lab	8	1.45	**4**	2.91	**3**	3.36	1	5.45

Table 23. Experimental rankings for the KITTI dataset.

Feature	Tracked Frames Wins Count	Tracked Frames Average Ranking	Rotation Error Wins Count	Rotation Error Average Ranking	Trans. Ang. Error Wins Count	Trans. Ang. Error Average Ranking	ATE Wins Count	ATE Average Ranking
Gray	4	3.25	1	4.75	2	4.25	1	4.38
Gray-A	3	2.88	0	4.38	0	4.62	1	4.50
Bit-Planes	**5**	**2.62**	1	3.50	2	**3.00**	0	3.75
SIFT	4	4.38	**3**	**2.62**	**3**	3.12	**4**	**3.00**
Siamese	3	4.12	0	5.62	0	4.75	1	4.88
AlexNet	2	2.75	0	5.88	0	5.75	0	6.38
RGB	3	**2.62**	2	3.62	1	4.38	0	4.50
Lab	0	7.50	1	5.62	0	6.12	1	4.62

Table 24. Experimental rankings for the ICL-NUIM dataset.

Feature	Tracked Frames Wins Count	Tracked Frames Average Ranking	Rotation Error Wins Count	Rotation Error Average Ranking	Trans. Ang. Error Wins Count	Trans. Ang. Error Average Ranking	ATE Wins Count	ATE Average Ranking
Gray	0	4.00	1	3.75	0	4.00	0	4.25
Gray-A	0	4.25	0	6.25	0	4.25	1	3.75
Bit-Planes	0	3.00	**3**	**2.00**	1	4.25	0	6.75
SIFT	**3**	**2.00**	0	5.00	0	6.00	0	8.00
Siamese	0	6.75	0	5.25	0	6.75	3	1.50
AlexNet	0	5.75	0	6.50	2	3.25	0	textbf3.00
RGB	1	4.00	0	3.50	1	**3.00**	0	4.25
Lab	1	5.75	0	3.75	0	4.50	0	4.50

Table 25. Experimental rankings for the Tsukuba dataset.

2.8. AlexNet Dimensionality Reduction
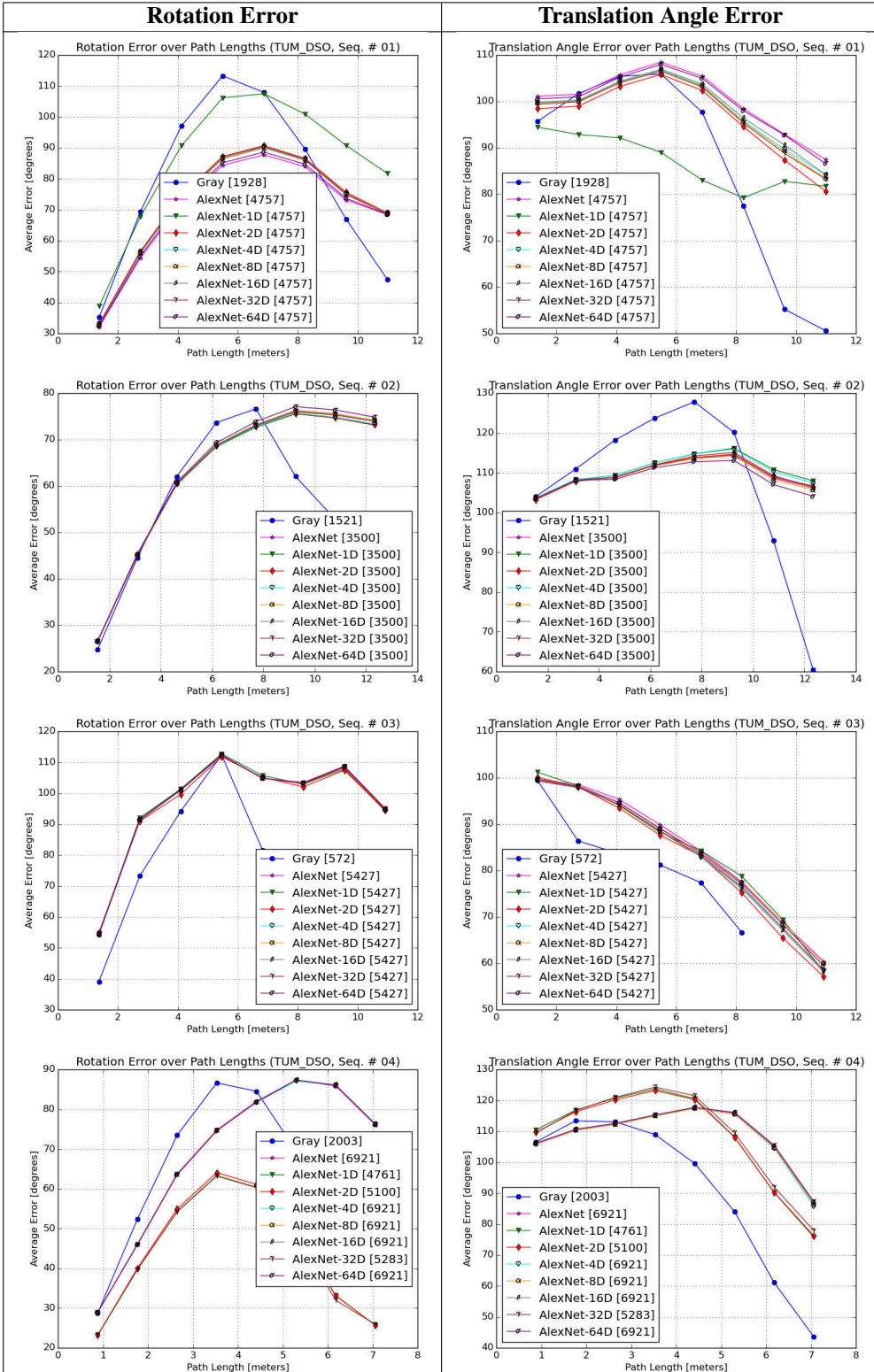
Figure 37. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (1-4).
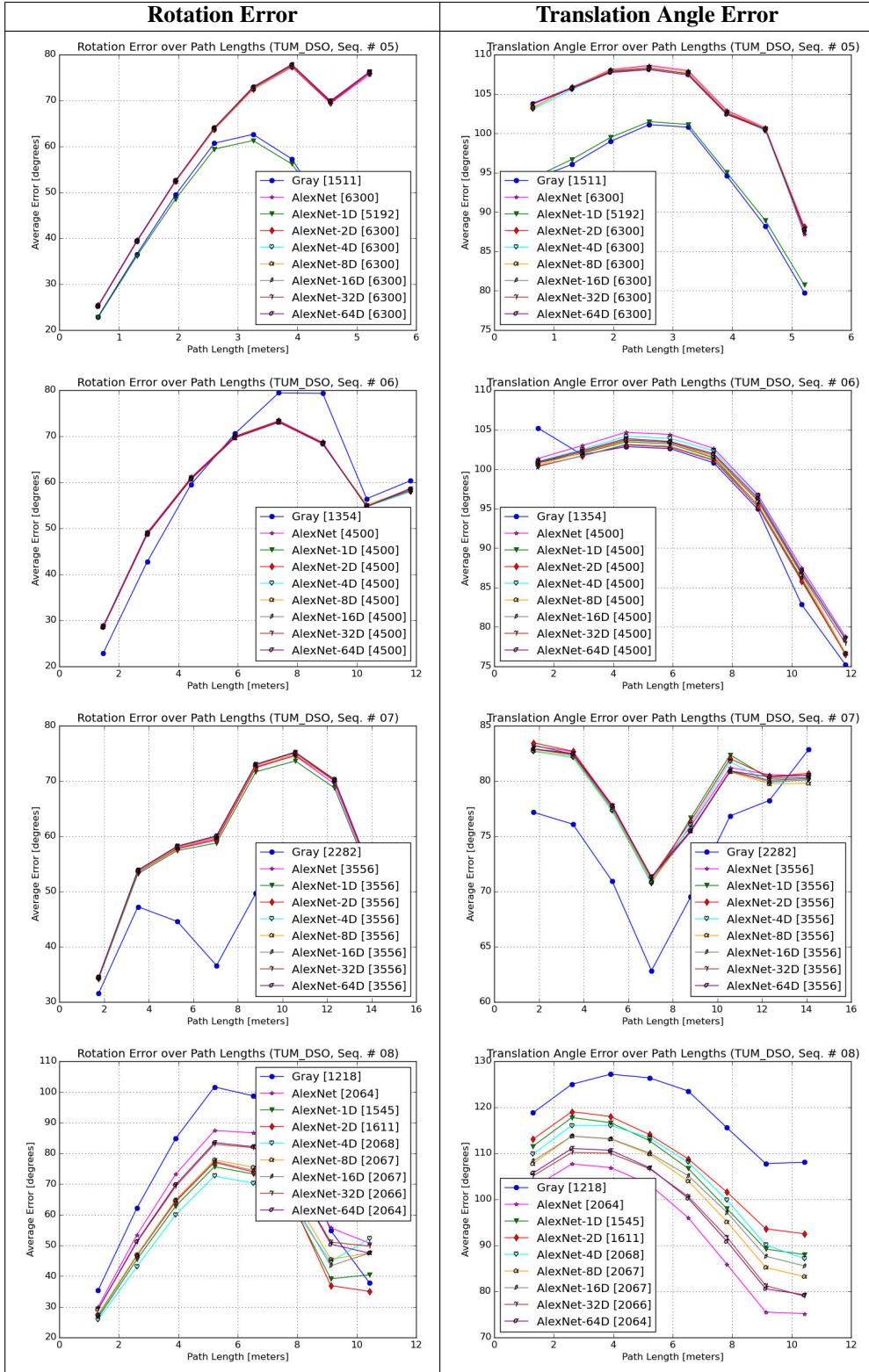
Figure 38.   Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (5-8).
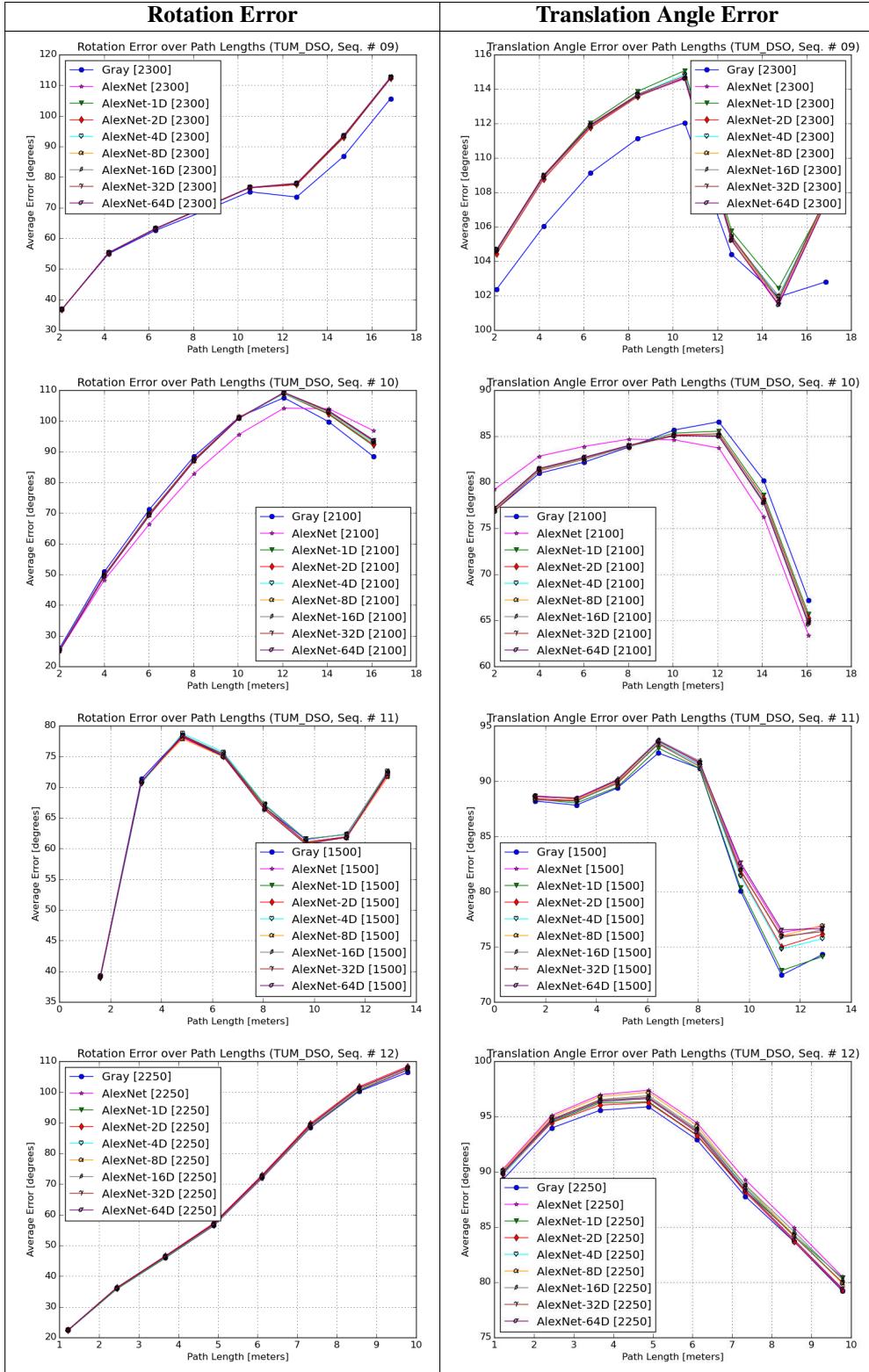
Figure 39. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (9-12).

| Rotation Error	Translation Angle Error
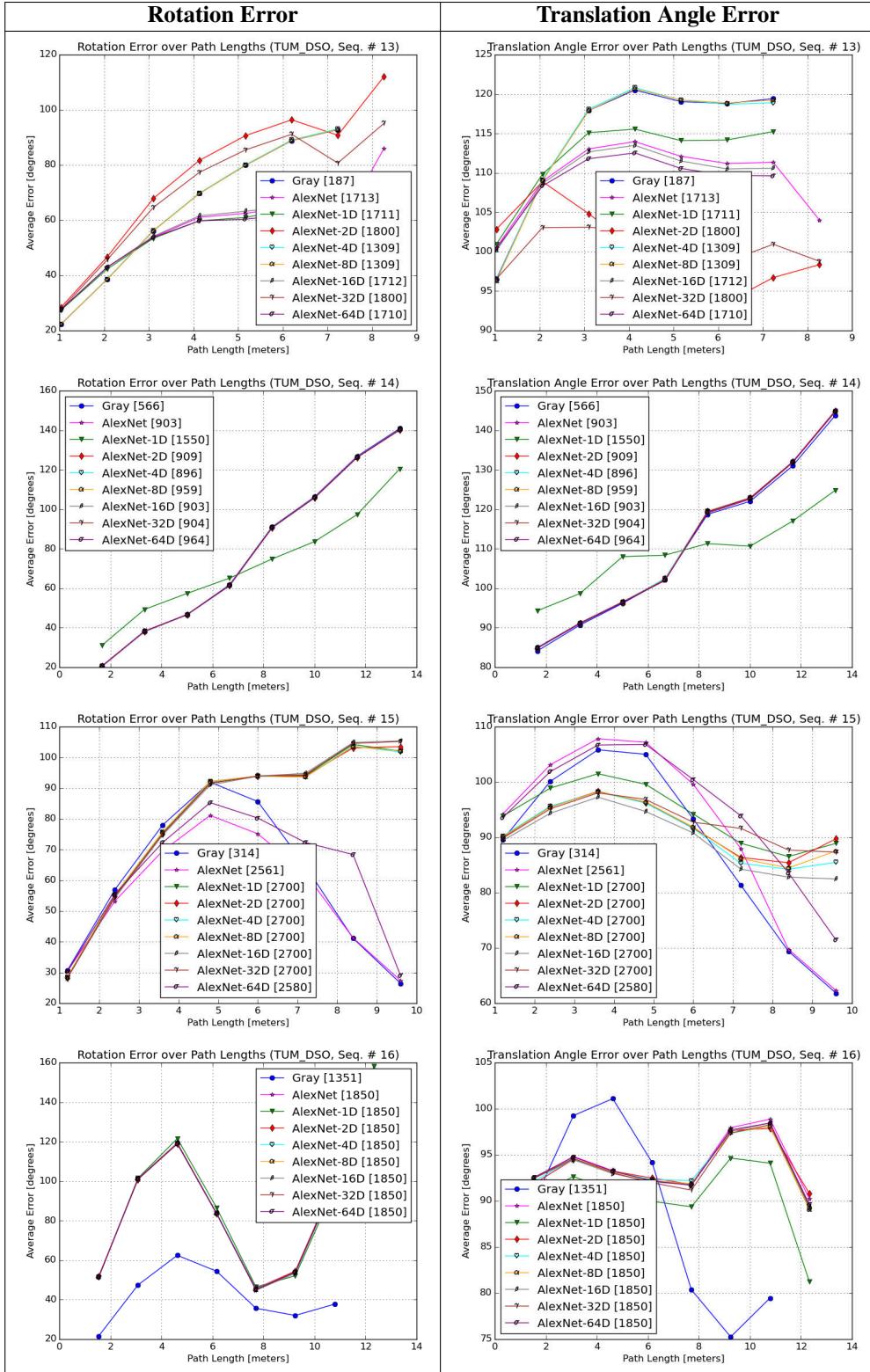
Figure 40. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (13-16).
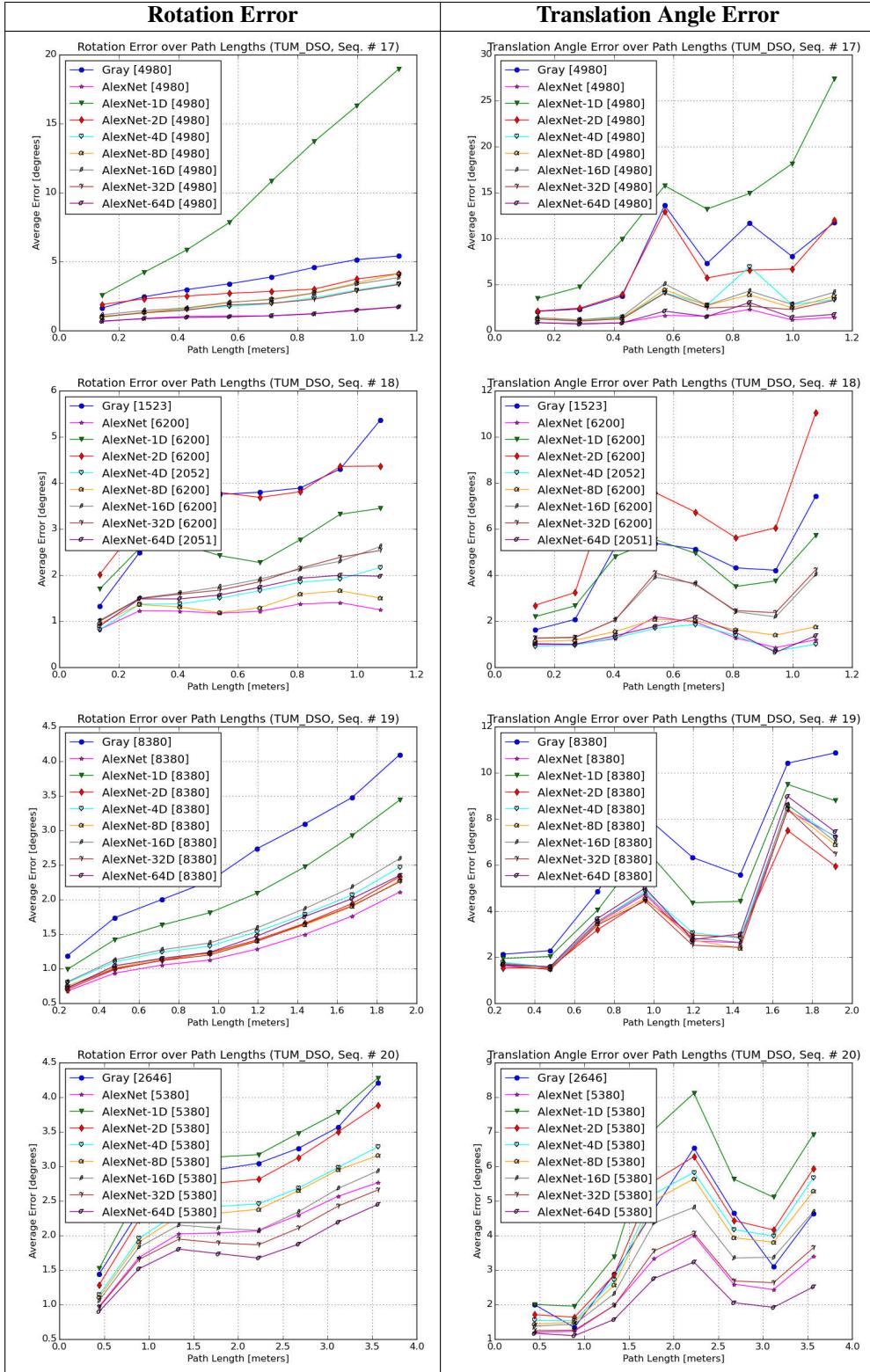
Figure 41. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (17-20).

Rotation Error	Translation Angle Error
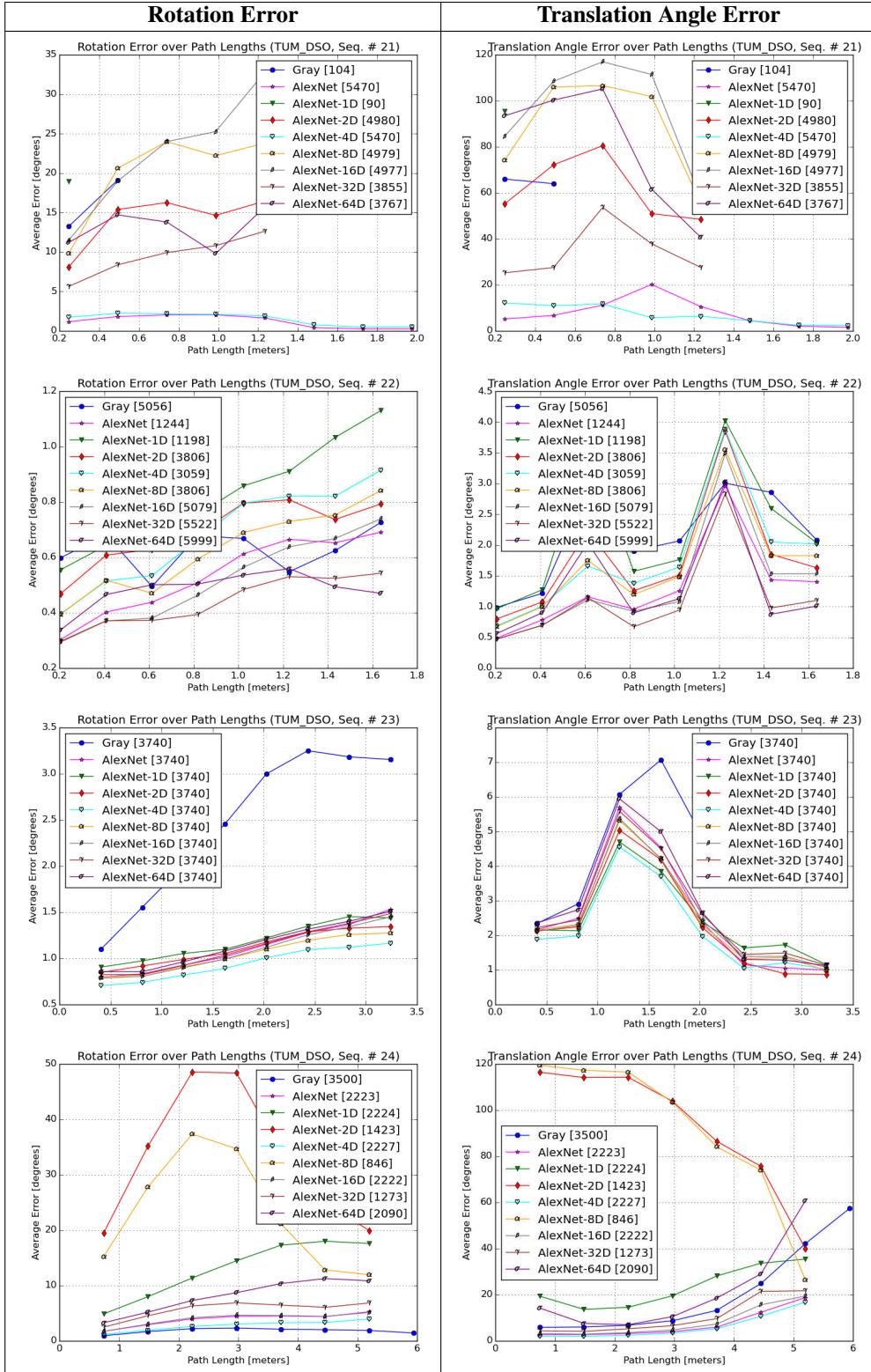
Figure 42. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (21-24).
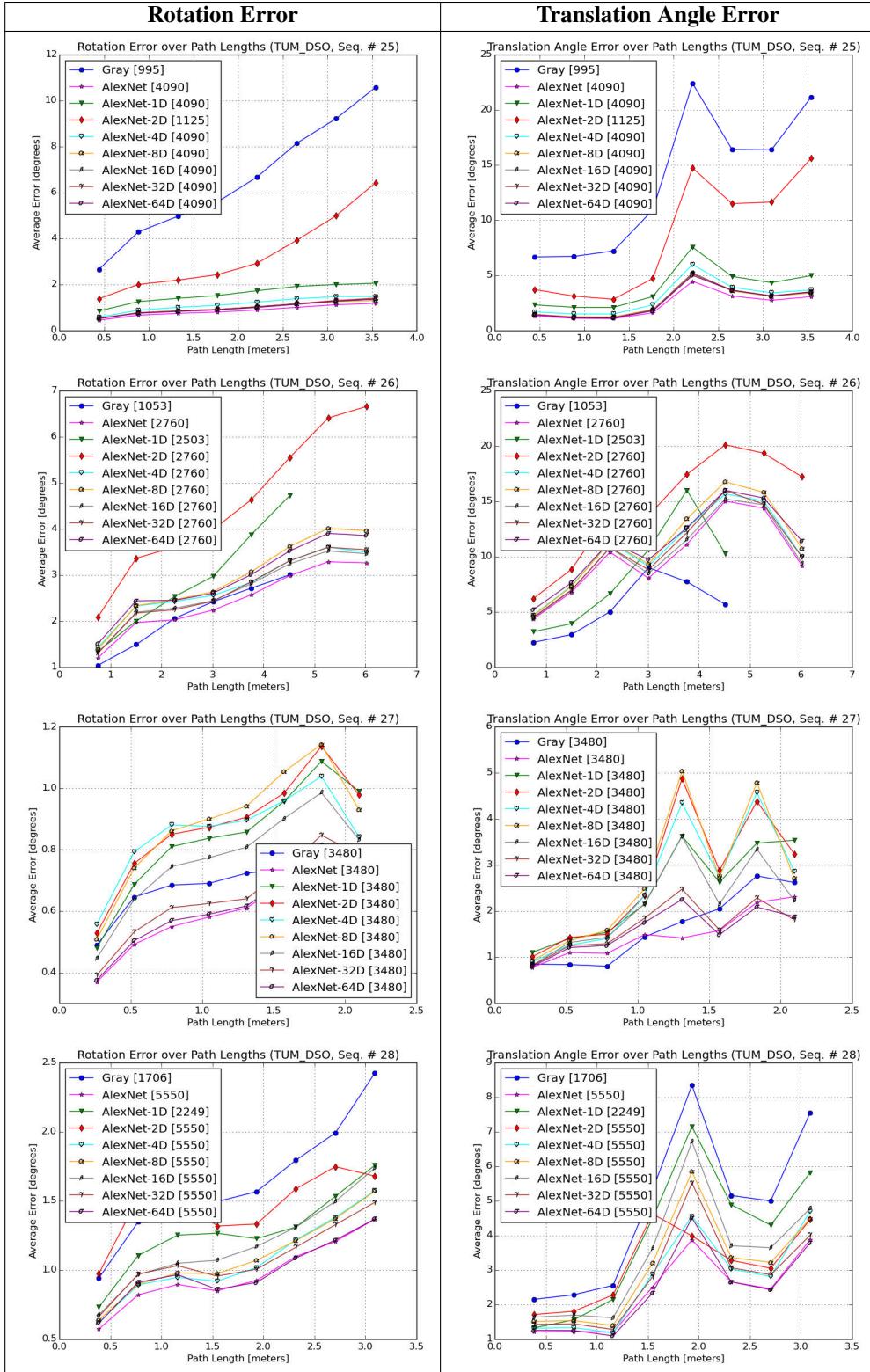
Figure 43. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (25-28).

| Rotation Error | Translation Angle Error |
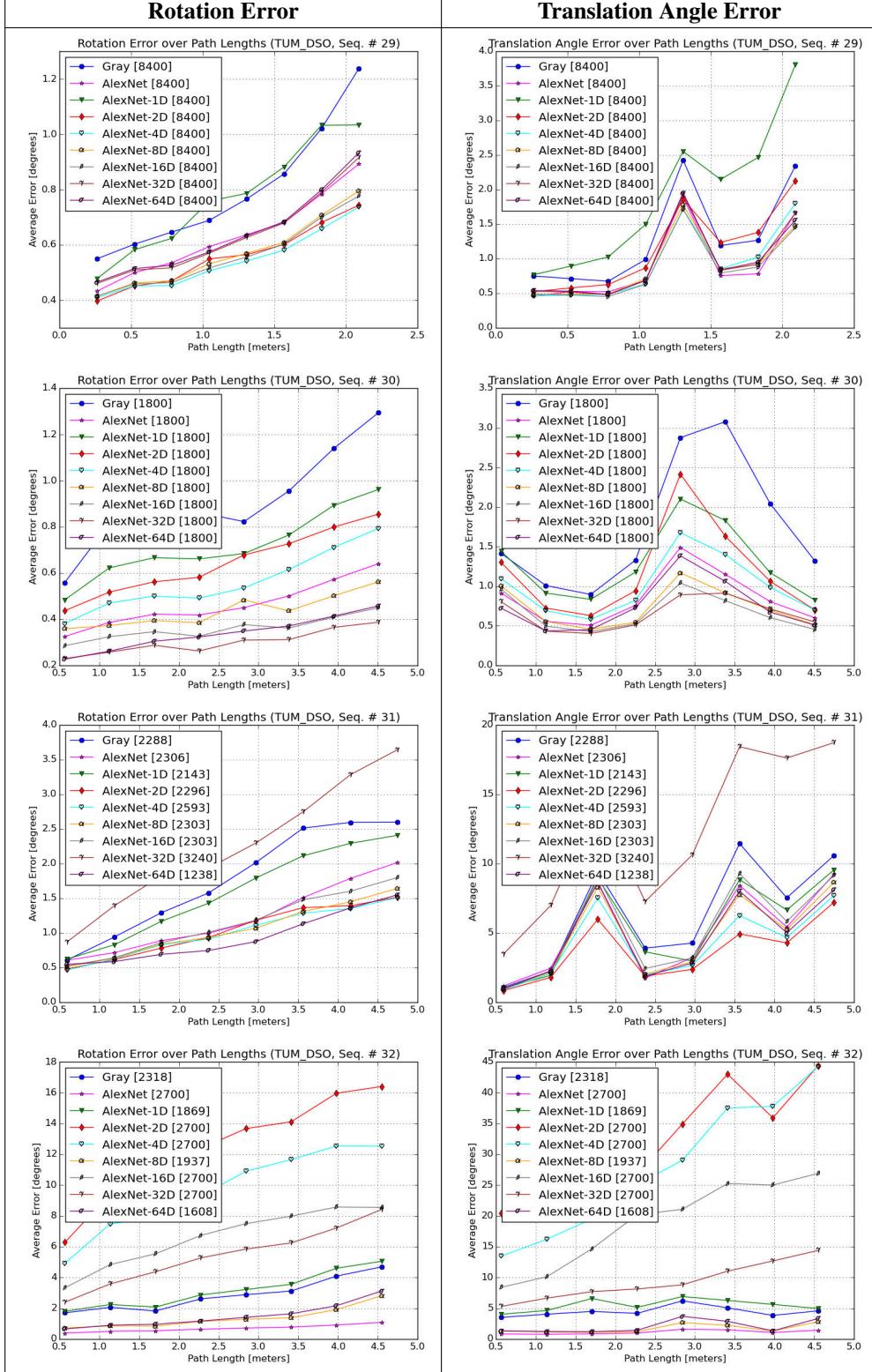
Figure 44. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (29-32).

| Rotation Error	Translation Angle Error
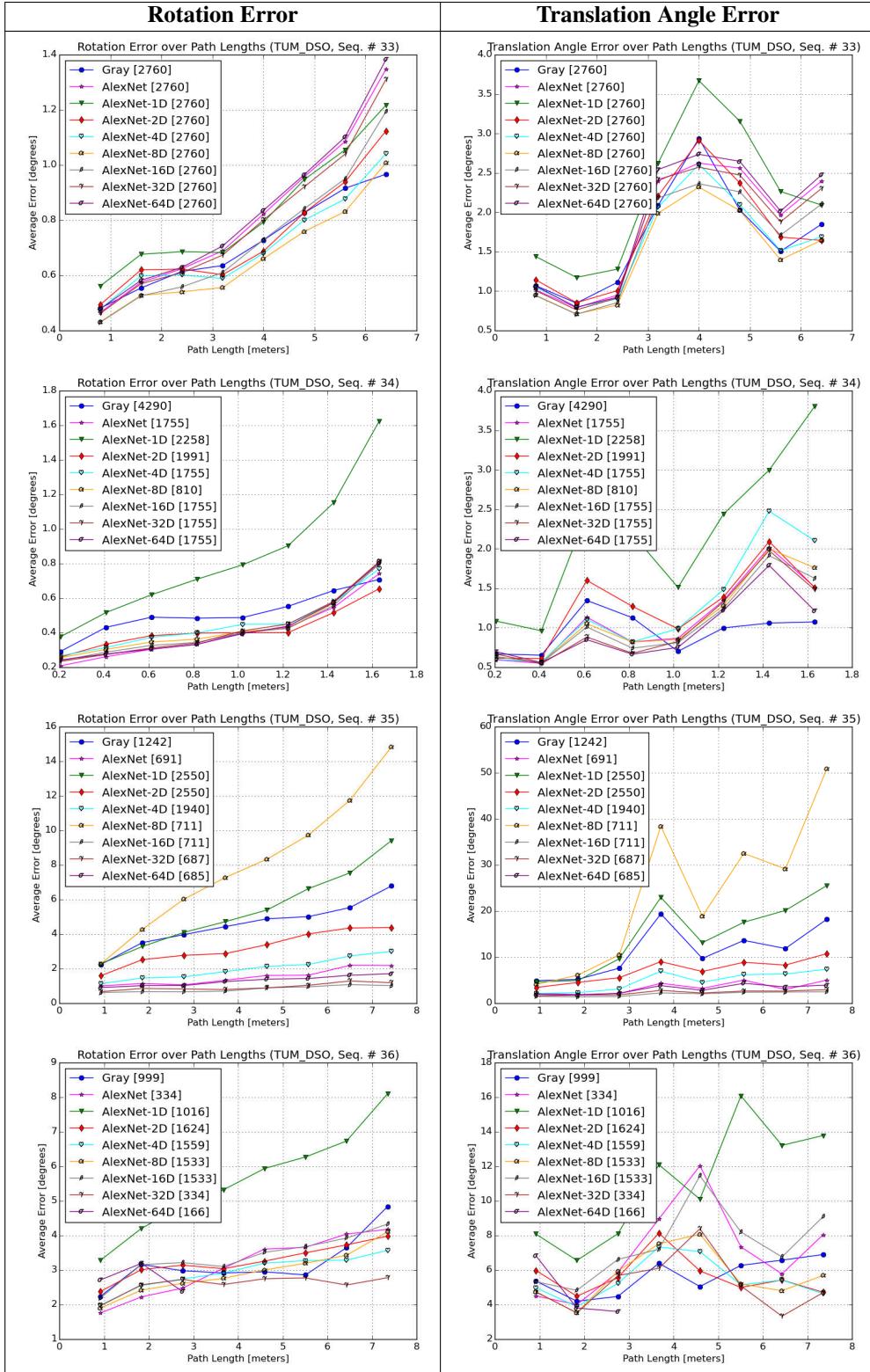
Figure 45. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (33-36).
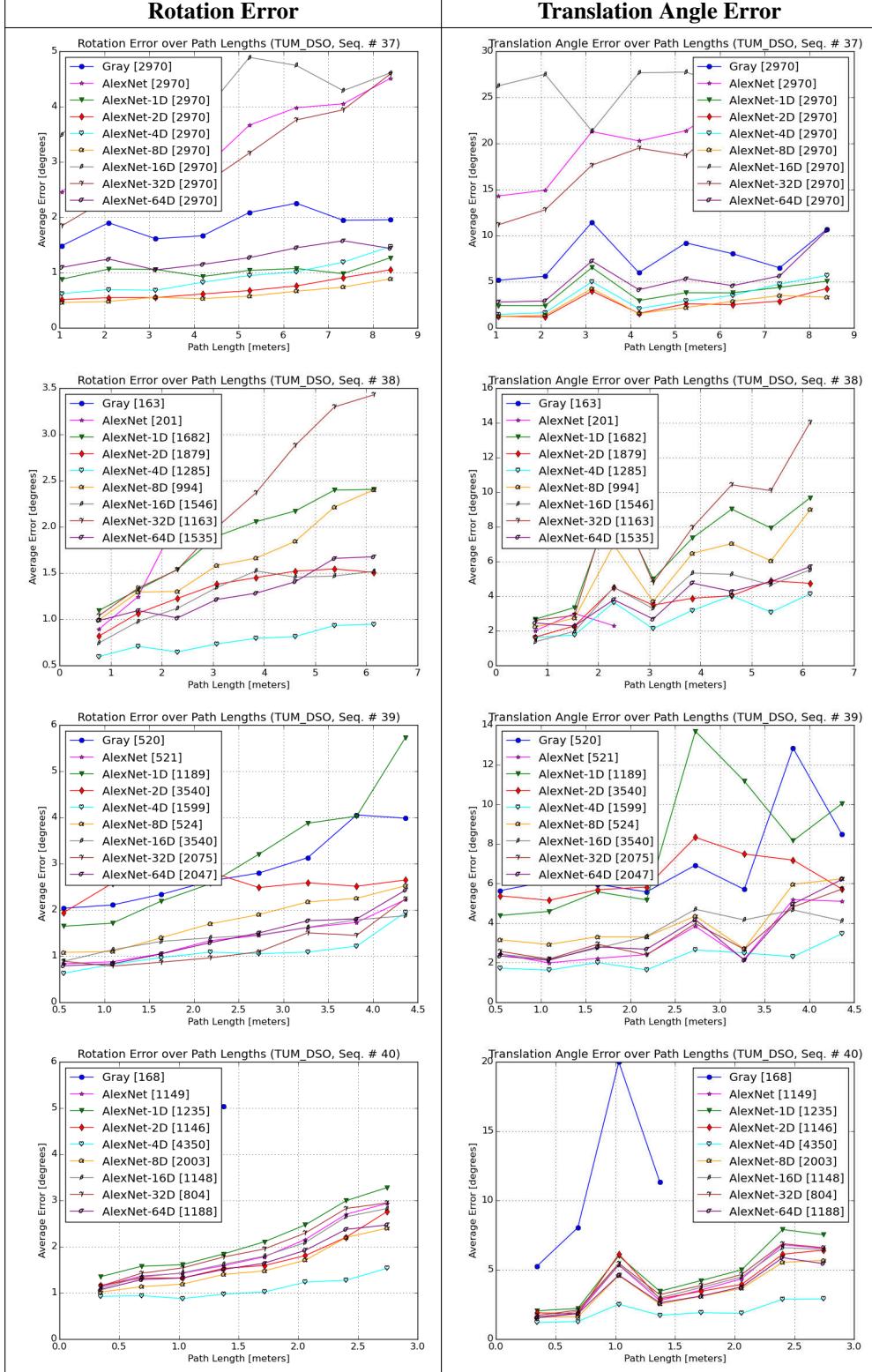
Figure 46. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (37-40).

	Rotation Error	Translation Angle Error
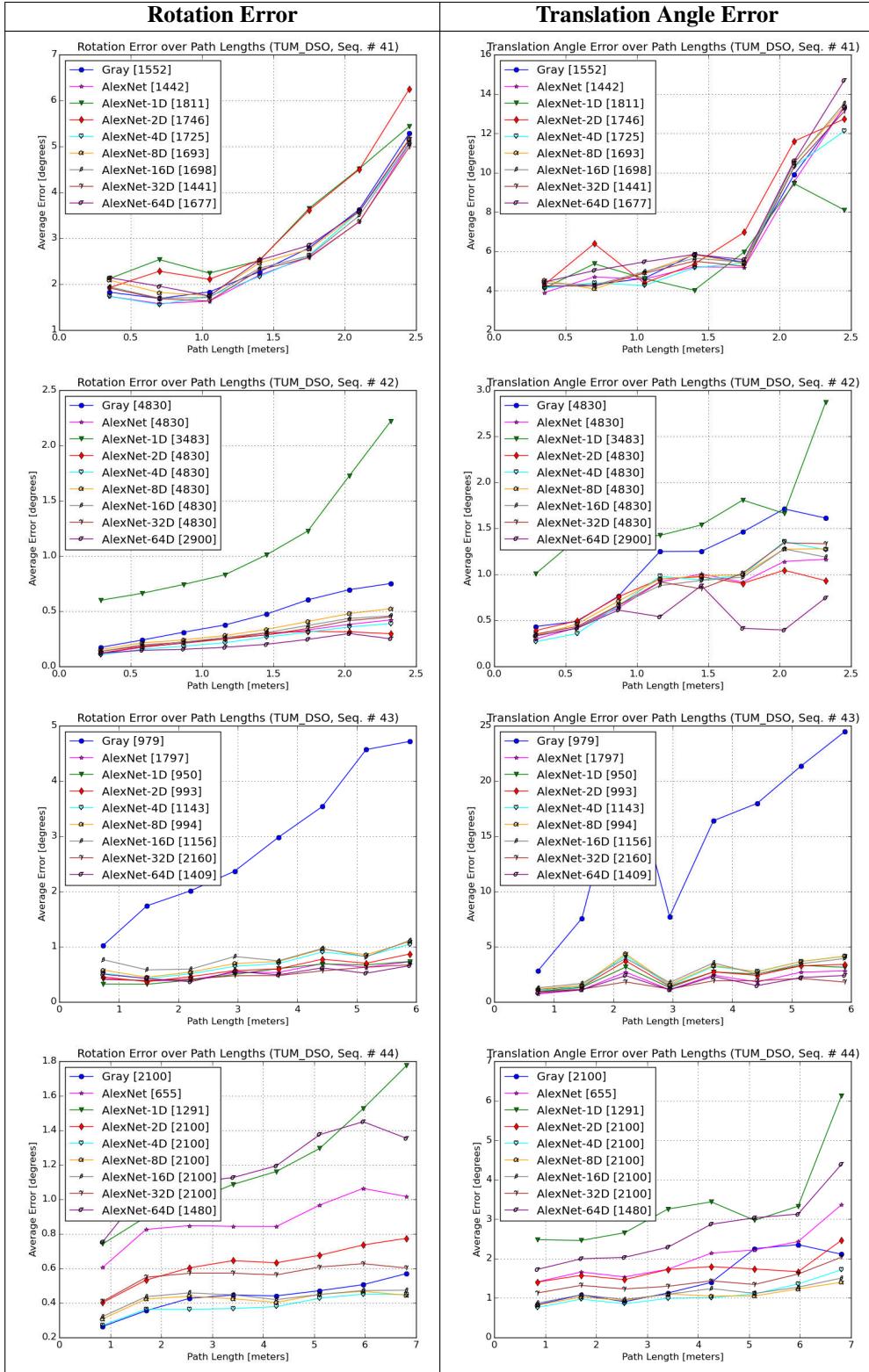
Figure 47. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (41-44).

| Rotation Error	Translation Angle Error
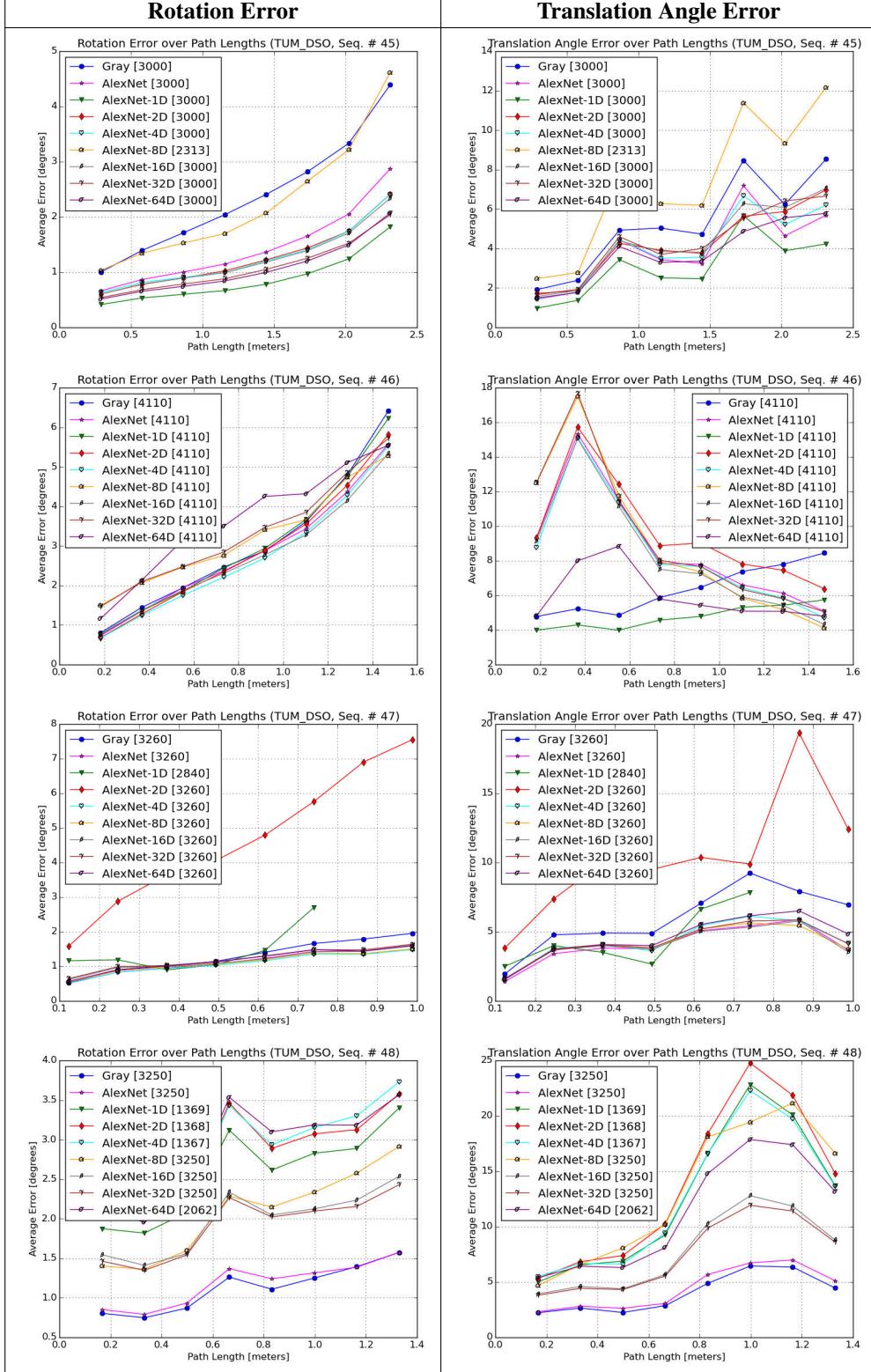
Figure 48. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (45-48).
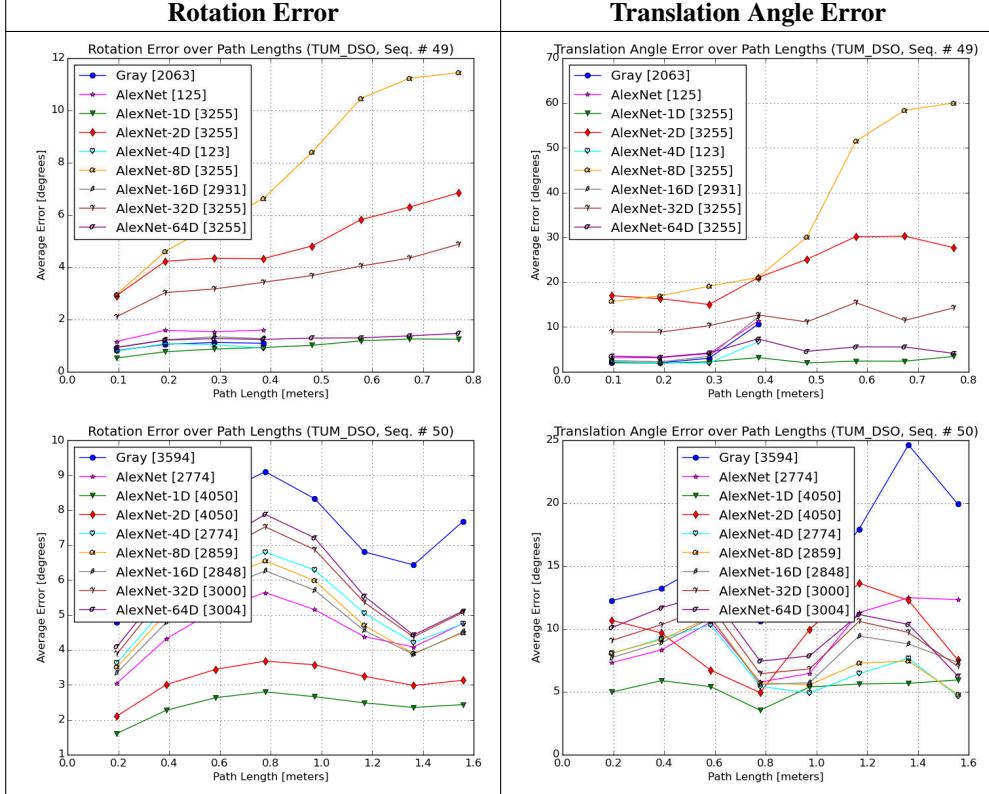
Figure 49. Alexnet feature dimensionality reduction: rotation and translation angle error plots for DSO sequences (49-50).

2.8.1 AlexNet Dimensionality Reduction: Rankings (Standard Competition)

Feature	Tracked Frames		Rotation Error		Trans. Ang. Error		ATE	
	Wins Count	Average Ranking	Wins Count	Average Ranking	Wins Count	Average Ranking	Wins Count	Average Ranking
Gray	20	5.20	8	5.82	**10**	5.76	**13**	4.84
AlexNet (96D)	32	2.86	**15**	**3.42**	9	4.44	3	4.58
AlexNet-1D	29	3.40	6	6.18	6	6.06	4	5.34
AlexNet-2D	**37**	2.22	0	5.82	4	5.60	4	5.12
AlexNet-4D	34	2.40	10	4.16	7	**4.04**	9	**4.24**
AlexNet-8D	32	2.64	3	4.94	2	4.96	6	5.00
AlexNet-16D	34	**2.10**	1	5.12	3	4.58	1	5.80
AlexNet-32D	36	2.34	3	4.82	5	4.74	3	5.62
AlexNet-64D	29	3.14	4	4.72	4	4.82	7	4.46

Table 26. Dimensionality reduction rankings for AlexNet features on the TUM DSO dataset.