Video Registration to SfM Models (Supplementary Material)

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For all 12 videos we list the absolute root mean squared (RMS) positional error (meters), orientational error (degrees) for different levels of outlier removal $\rho_{1,\dots,5}$. We also provide the relative improvements to ASPnP baseline column A.

Video 1

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.15	0.092	0.16	0.13	0.15	0.083	2	1.9	0.06	0.055	0.06	**0.054**
$\rho = \rho_2$	0.14	0.09	0.15	0.13	0.14	0.08	1.8	1.8	0.06	0.054	0.059	**0.054**
$\rho = \rho_3$	3.4	3.4	3.2	2.4	3.4	2.4	2.7	2.7	**1.1**	1.1	1.4	1.3
$\rho = \rho_4$	12	12	11	9.9	12	9.8	2.6	2.6	**1.4**	1.5	1.7	1.6
$\rho = \rho_5$	22	23	19	14	17	14	6.3	6.4	1.9	1.7	2	**1.6**
$\rho = \rho_1$	0.32	0.24	0.33	0.31	0.32	0.23	0.62	0.58	0.2	**0.19**	0.2	0.19
$\rho = \rho_2$	0.31	0.24	0.33	0.3	0.31	0.22	0.85	0.81	0.2	**0.2**	0.2	0.2
$\rho = \rho_3$	3.1	3	3.1	2.5	3.1	2.4	3.3	3.3	2.8	2.5	2.2	**2.1**
$\rho = \rho_4$	7.1	7	7.2	5.9	7.1	5.9	**4**	4	6.1	5.9	5.1	5
$\rho = \rho_5$	9.4	9.3	9.9	7.7	9.1	7.7	6.7	**6.6**	9.8	10	11	10

Table 1: Vid. 1 absolute RMS positional (rows 1:5) and orient. error (rows 6:10).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.148	1.6	0.926	1.09	1	1.78	0.0754	0.0773	2.45	2.7	2.46	**2.71**
$\rho = \rho_2$	0.141	1.57	0.929	1.1	1	1.78	0.0772	0.0805	2.37	2.63	2.39	**2.64**
$\rho = \rho_3$	3.42	0.994	1.08	1.4	1	1.4	1.26	1.27	**3.12**	2.99	2.4	2.54
$\rho = \rho_4$	12.3	1	1.16	1.24	1.06	1.25	4.74	4.75	**9.03**	8.18	7.25	7.74
$\rho = \rho_5$	22.4	0.994	1.21	1.58	1.32	1.57	3.55	3.53	11.9	13.4	11.3	**14**
$\rho = \rho_1$	0.324	1.33	0.985	1.05	1	1.43	0.519	0.557	1.64	**1.68**	1.64	1.66
$\rho = \rho_2$	0.314	1.29	0.962	1.06	1	1.42	0.372	0.39	1.57	**1.58**	1.58	1.57
$\rho = \rho_3$	3.08	1.03	0.989	1.25	1	1.3	0.937	0.942	1.1	1.21	1.42	**1.48**
$\rho = \rho_4$	7.07	1.01	0.98	1.19	0.996	1.19	**1.76**	1.75	1.17	1.19	1.39	1.41
$\rho = \rho_5$	9.36	1.01	0.943	1.21	1.02	1.21	1.41	**1.42**	0.956	0.918	0.89	0.903

Table 2: Vid. 1 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orient. error.

Video 2

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.11	0.094	0.11	0.11	0.11	0.079	0.093	0.087	0.068	0.069	**0.066**	0.069
$\rho = \rho_2$	0.11	0.094	0.11	0.1	0.11	0.081	0.1	0.098	0.07	0.07	**0.069**	0.07
$\rho = \rho_3$	0.43	0.43	0.27	0.12	0.43	0.11	0.16	0.15	0.072	0.072	**0.069**	0.071
$\rho = \rho_4$	3.5	3.5	2.7	0.95	3.5	0.95	2.2	2.2	0.073	0.072	**0.071**	0.072
$\rho = \rho_5$	4.8	4.8	4	0.93	4.7	0.93	3	3.1	0.078	0.076	0.078	**0.076**
$\rho = \rho_1$	0.32	0.31	0.32	0.31	0.32	0.31	0.32	0.31	0.26	0.26	**0.25**	0.25
$\rho = \rho_2$	0.33	0.32	0.32	0.32	0.33	0.31	0.32	0.33	0.27	0.27	**0.26**	0.26
$\rho = \rho_3$	0.5	0.49	0.52	0.46	0.5	0.45	0.38	0.38	0.27	0.27	**0.27**	0.27
$\rho = \rho_4$	0.98	0.98	1	0.41	0.99	**0.39**	0.84	0.81	0.52	0.52	0.48	0.47
$\rho = \rho_5$	1.4	1.4	1.4	0.6	1.4	0.58	1.3	1.2	0.8	0.8	0.56	**0.56**

Table 3: Vid. 2 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.114	1.22	1.02	1.08	1	1.45	1.22	1.31	1.68	1.67	**1.73**	1.67
$\rho = \rho_2$	0.111	1.17	1.03	1.08	1	1.37	1.11	1.13	1.57	1.58	**1.61**	1.58
$\rho = \rho_3$	0.429	1	1.61	3.55	1	4.01	2.6	2.89	5.93	5.95	**6.24**	6.02
$\rho = \rho_4$	3.53	1	1.31	3.7	1.01	3.7	1.59	1.62	48.3	49	**49.8**	49.3
$\rho = \rho_5$	4.77	1	1.19	5.12	1.01	5.13	1.58	1.55	61.2	62.9	61.4	**62.9**
$\rho = \rho_1$	0.324	1.04	1.02	1.03	1	1.06	1.03	1.04	1.27	1.26	**1.29**	1.28
$\rho = \rho_2$	0.326	1.02	1.01	1.03	1	1.04	1	0.998	1.22	1.21	**1.24**	1.24
$\rho = \rho_3$	0.498	1.01	0.952	1.09	1	1.11	1.3	1.33	1.82	1.81	**1.83**	1.82
$\rho = \rho_4$	0.984	1	0.947	2.43	0.996	**2.5**	1.17	1.21	1.89	1.9	2.07	2.08
$\rho = \rho_5$	1.4	1	0.97	2.35	0.997	2.42	1.1	1.13	1.75	1.76	2.51	**2.52**

Table 4: Vid. 2 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 3

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.11	0.25	0.22	0.087	0.1	0.12	2.1	1.9	0.082	0.077	0.078	**0.076**
$\rho = \rho_2$	0.12	0.24	0.2	0.091	0.1	0.12	1	1	**0.067**	0.071	0.069	0.072
$\rho = \rho_3$	13	13	12	11	13	11	6.2	6.1	2	1.6	**1.4**	1.5
$\rho = \rho_4$	19	19	17	8.4	15	8.2	10	10	3.9	3.7	3.5	**3.5**
$\rho = \rho_5$	43	43	32	12	23	12	22	22	6.8	**6.3**	8.4	8.3
$\rho = \rho_1$	0.27	0.45	0.25	**0.22**	0.25	0.28	1.4	1.4	0.23	0.25	0.23	0.25
$\rho = \rho_2$	0.28	0.45	0.26	0.23	0.26	0.28	1.3	1.2	**0.21**	0.24	0.21	0.25
$\rho = \rho_3$	5.2	5.3	5.1	**4.7**	5.2	4.8	6.6	6.5	5.5	5.7	5	5.2
$\rho = \rho_4$	14	14	14	6.7	15	**6.7**	9.2	9.1	13	13	8.8	9.2
$\rho = \rho_5$	27	27	26	**4.9**	27	5.3	27	27	31	32	16	16

Table 5: Vid. 3 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.115	0.466	0.532	1.31	1.12	0.98	0.0547	0.0606	1.4	1.49	1.47	**1.5**
$\rho = \rho_2$	0.116	0.474	0.578	1.27	1.12	0.957	0.113	0.116	**1.72**	1.63	1.68	1.61
$\rho = \rho_3$	12.8	1	1.09	1.11	1	1.12	2.06	2.11	6.55	7.88	**8.84**	8.67
$\rho = \rho_4$	18.7	0.996	1.11	2.24	1.23	2.29	1.84	1.85	4.8	5.11	5.27	**5.42**
$\rho = \rho_5$	43.4	0.998	1.34	3.75	1.9	3.64	1.93	1.95	6.39	**6.91**	5.14	5.24
$\rho = \rho_1$	0.272	0.61	1.07	**1.24**	1.09	0.983	0.189	0.198	1.16	1.07	1.19	1.07
$\rho = \rho_2$	0.277	0.614	1.06	1.22	1.08	0.973	0.22	0.232	**1.3**	1.14	1.29	1.13
$\rho = \rho_3$	5.17	0.972	1.01	**1.1**	1	1.08	0.779	0.798	0.946	0.905	1.04	0.997
$\rho = \rho_4$	13.8	0.993	1.01	2.05	0.916	**2.07**	1.51	1.52	1.05	1.1	1.57	1.5
$\rho = \rho_5$	26.6	0.998	1.04	**5.38**	0.969	5.05	0.999	1	0.854	0.832	1.65	1.62

Table 6: Vid. 3 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 4

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.064	0.061	0.059	0.053	0.064	0.054	0.07	0.069	0.049	0.049	**0.047**	0.047
$\rho = \rho_2$	0.064	0.061	0.059	0.053	0.064	0.054	0.07	0.069	0.049	0.049	**0.047**	0.047
$\rho = \rho_3$	0.064	0.061	0.059	0.053	0.064	0.054	0.07	0.069	0.049	0.049	**0.047**	0.047
$\rho = \rho_4$	0.064	0.061	0.059	0.053	0.064	0.054	0.07	0.069	0.049	0.049	**0.047**	0.047
$\rho = \rho_5$	0.064	0.061	0.059	0.053	0.064	0.054	0.07	0.069	0.049	0.049	**0.047**	0.047
$\rho = \rho_1$	0.28	0.27	0.28	0.28	0.28	0.26	0.29	0.28	0.24	0.23	0.24	**0.23**
$\rho = \rho_2$	0.28	0.27	0.28	0.28	0.28	0.26	0.29	0.28	0.24	0.23	0.24	**0.23**
$\rho = \rho_3$	0.28	0.27	0.28	0.28	0.28	0.26	0.29	0.28	0.24	0.23	0.24	**0.23**
$\rho = \rho_4$	0.28	0.27	0.28	0.28	0.28	0.26	0.29	0.28	0.24	0.23	0.24	**0.23**
$\rho = \rho_5$	0.28	0.27	0.28	0.28	0.28	0.26	0.29	0.28	0.24	0.23	0.24	**0.23**

Table 7: Vid. 4 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.0635	1.05	1.07	1.19	1	1.19	0.902	0.924	1.3	1.31	**1.36**	1.36
$\rho = \rho_2$	0.0635	1.05	1.07	1.19	1	1.19	0.902	0.924	1.3	1.31	**1.36**	1.36
$\rho = \rho_3$	0.0635	1.05	1.07	1.19	1	1.19	0.902	0.924	1.3	1.31	**1.36**	1.36
$\rho = \rho_4$	0.0635	1.05	1.07	1.19	1	1.19	0.902	0.924	1.3	1.31	**1.36**	1.36
$\rho = \rho_5$	0.0635	1.05	1.07	1.19	1	1.19	0.902	0.924	1.3	1.31	**1.36**	1.36
$\rho = \rho_1$	0.284	1.04	1.01	1.02	1	1.08	0.965	1.02	1.17	1.21	1.17	**1.21**
$\rho = \rho_2$	0.284	1.04	1.01	1.02	1	1.08	0.965	1.02	1.17	1.21	1.17	**1.21**
$\rho = \rho_3$	0.284	1.04	1.01	1.02	1	1.08	0.965	1.02	1.17	1.21	1.17	**1.21**
$\rho = \rho_4$	0.284	1.04	1.01	1.02	1	1.08	0.965	1.02	1.17	1.21	1.17	**1.21**
$\rho = \rho_5$	0.284	1.04	1.01	1.02	1	1.08	0.965	1.02	1.17	1.21	1.17	**1.21**

Table 8: Vid. 4 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 5

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.18	0.2	0.8	0.13	0.18	0.17	0.62	0.98	**0.08**	0.091	0.082	0.091
$\rho = \rho_2$	0.23	0.23	0.22	0.19	0.23	0.19	0.36	0.63	0.076	0.091	**0.076**	0.091
$\rho = \rho_3$	11	11	9.7	11	11	11	6.5	6.3	0.82	**0.58**	0.93	0.73
$\rho = \rho_4$	20	20	18	17	18	18	12	12	1.1	**0.36**	0.47	0.4
$\rho = \rho_5$	43	43	30	11	37	11	21	23	1.4	0.96	1.4	**0.92**
$\rho = \rho_1$	0.2	0.16	0.61	0.17	0.2	0.14	0.2	0.2	**0.13**	0.13	0.13	0.13
$\rho = \rho_2$	0.2	0.16	0.19	0.17	0.2	0.14	0.17	0.17	0.14	0.14	**0.14**	0.14
$\rho = \rho_3$	1.2	1.1	1.3	1.2	1.1	1.1	0.55	**0.54**	0.83	0.82	0.66	0.65
$\rho = \rho_4$	5	5	5.4	5.2	5.3	5.1	4.4	4.5	3.5	3.4	3.2	**2.8**
$\rho = \rho_5$	10	10	11	6.8	13	**6.8**	8.4	8.6	7.8	8.1	7.6	7.7

Table 9: Vid. 5 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.179	0.883	0.223	1.34	1	1.07	0.286	0.182	**2.24**	1.96	2.18	1.95
$\rho = \rho_2$	0.228	1.01	1.05	1.22	1	1.22	0.633	0.363	2.98	2.49	**3**	2.51
$\rho = \rho_3$	11.4	1	1.17	1.01	1.07	1.01	1.76	1.82	14	**19.7**	12.2	15.7
$\rho = \rho_4$	20	0.997	1.1	1.14	1.13	1.14	1.61	1.67	17.8	**55.6**	42.7	50.4
$\rho = \rho_5$	42.7	0.996	1.4	3.79	1.16	3.77	1.99	1.86	31.5	44.6	30.2	**46.3**
$\rho = \rho_1$	0.203	1.25	0.331	1.17	1	1.44	1	1	**1.53**	1.51	1.52	1.51
$\rho = \rho_2$	0.203	1.24	1.06	1.18	1	1.41	1.21	1.18	1.48	1.47	**1.5**	1.46
$\rho = \rho_3$	1.16	1.04	0.882	1.01	1.02	1.04	2.1	**2.15**	1.4	1.41	1.75	1.79
$\rho = \rho_4$	5.04	1.01	0.939	0.975	0.95	0.98	1.15	1.13	1.44	1.48	1.56	**1.79**
$\rho = \rho_5$	10.5	1	0.923	1.53	0.836	**1.55**	1.24	1.22	1.35	1.3	1.38	1.36

Table 10: Vid. 5 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 6

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.19	0.15	0.18	0.17	0.19	0.11	0.25	0.22	0.094	0.095	**0.087**	0.095
$\rho = \rho_2$	0.2	0.15	0.18	0.17	0.19	0.11	0.45	0.43	0.081	0.076	0.084	**0.072**
$\rho = \rho_3$	0.41	0.42	0.33	0.13	0.41	0.12	1.3	1.2	0.11	**0.095**	0.16	0.12
$\rho = \rho_4$	3.1	3.1	2.9	0.4	3.1	0.43	0.55	0.53	0.1	**0.085**	0.11	0.092
$\rho = \rho_5$	24	23	20	2.2	8.9	2.1	0.55	0.53	**0.084**	0.089	0.99	0.85
$\rho = \rho_1$	0.24	0.2	0.24	0.22	0.24	0.18	0.27	0.26	0.18	**0.17**	0.18	0.17
$\rho = \rho_2$	0.24	0.2	0.24	0.22	0.24	0.18	0.47	0.48	0.18	**0.17**	0.18	0.17
$\rho = \rho_3$	0.38	0.34	0.39	0.27	0.38	0.25	0.79	0.76	0.26	0.26	0.18	**0.18**
$\rho = \rho_4$	0.54	0.5	0.53	0.4	0.53	**0.4**	0.55	0.55	0.57	0.57	0.43	0.42
$\rho = \rho_5$	2.8	2.7	3	1	3.4	1	**0.41**	0.41	3.4	3.4	1	1

Table 11: Vid. 6 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.194	1.32	1.08	1.16	1.02	1.81	0.782	0.888	2.06	2.04	**2.24**	2.04
$\rho = \rho_2$	0.199	1.37	1.08	1.19	1.03	1.87	0.444	0.461	2.45	2.63	2.36	**2.76**
$\rho = \rho_3$	0.412	0.97	1.25	3.21	1.01	3.57	0.328	0.332	3.89	**4.32**	2.57	3.45
$\rho = \rho_4$	3.13	1	1.06	7.92	1	7.23	5.71	5.86	30.8	**37**	29	34
$\rho = \rho_5$	23.6	1	1.16	10.8	2.65	11.1	42.6	44.4	**281**	266	23.9	27.7
$\rho = \rho_1$	0.239	1.19	0.987	1.08	1	1.33	0.899	0.931	1.32	**1.4**	1.29	1.37
$\rho = \rho_2$	0.238	1.19	0.989	1.08	1	1.33	0.503	0.498	1.33	**1.38**	1.3	1.37
$\rho = \rho_3$	0.376	1.12	0.973	1.41	0.992	1.51	0.477	0.492	1.44	1.47	2.09	**2.11**
$\rho = \rho_4$	0.539	1.07	1.01	1.36	1.01	**1.36**	0.99	0.981	0.946	0.954	1.24	1.27
$\rho = \rho_5$	2.76	1.01	0.908	2.7	0.807	2.66	**6.7**	6.69	0.814	0.812	2.75	2.68

Table 12: Vid. 6 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 7

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.19	0.12	0.18	0.17	0.19	0.093	3.2	3.2	**0.071**	0.074	0.081	0.079
$\rho = \rho_2$	0.2	0.12	0.19	0.17	0.19	0.09	0.74	0.69	**0.07**	0.073	0.079	0.077
$\rho = \rho_3$	2	1.9	1.9	1.6	1.9	1.6	1.9	1.8	**0.071**	0.075	0.08	0.079
$\rho = \rho_4$	3.5	3.5	3.2	1.2	2.3	1.2	5.1	5.2	**0.074**	0.078	0.079	0.081
$\rho = \rho_5$	17	17	14	4.1	4.6	4	10	10	**0.069**	0.073	0.075	0.076
$\rho = \rho_1$	0.39	0.32	0.36	0.35	0.38	0.29	0.71	0.68	0.29	0.28	0.29	**0.28**
$\rho = \rho_2$	0.4	0.32	0.37	0.36	0.39	0.29	0.48	0.5	0.28	0.28	0.28	**0.28**
$\rho = \rho_3$	0.6	0.53	0.59	0.52	0.6	0.46	0.45	**0.45**	0.77	0.77	0.77	0.77
$\rho = \rho_4$	1.1	1	1.2	0.51	1.9	**0.45**	1.8	1.7	1.5	1.5	1.5	1.6
$\rho = \rho_5$	3.5	3.4	3.7	0.67	4.2	**0.63**	3.5	3.6	3.9	4.1	2.9	2.9

Table 13: Vid. 7 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.194	1.65	1.09	1.15	1.01	2.08	0.0606	0.0612	**2.73**	2.6	2.4	2.46
$\rho = \rho_2$	0.196	1.65	1.06	1.16	1.01	2.18	0.265	0.284	**2.81**	2.68	2.48	2.53
$\rho = \rho_3$	1.96	1.01	1.03	1.22	1.01	1.23	1.03	1.12	**27.7**	26	24.6	24.9
$\rho = \rho_4$	3.5	1.01	1.11	2.85	1.52	2.93	0.683	0.669	**47.2**	44.6	44.2	43.1
$\rho = \rho_5$	17.1	1	1.21	4.17	3.75	4.25	1.72	1.71	**248**	236	229	226
$\rho = \rho_1$	0.39	1.23	1.07	1.1	1.01	1.35	0.553	0.578	1.36	1.38	1.35	**1.39**
$\rho = \rho_2$	0.398	1.26	1.06	1.11	1.01	1.39	0.83	0.802	1.42	1.43	1.42	**1.44**
$\rho = \rho_3$	0.603	1.15	1.02	1.15	1.01	1.31	1.33	**1.36**	0.786	0.787	0.784	0.789
$\rho = \rho_4$	1.12	1.08	0.975	2.19	0.596	**2.48**	0.641	0.652	0.741	0.735	0.738	0.718
$\rho = \rho_5$	3.48	1.02	0.94	5.19	0.826	**5.5**	0.983	0.97	0.892	0.851	1.2	1.2

Table 14: Vid. 7 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 8

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.26	0.18	0.27	0.24	0.26	0.16	0.25	0.25	0.074	**0.056**	0.075	0.061
$\rho = \rho_2$	0.27	0.18	0.28	0.24	0.27	0.17	0.18	0.19	0.083	**0.063**	0.083	0.067
$\rho = \rho_3$	8.6	8.6	8.2	7.8	8.6	7.9	3.6	3.8	0.31	**0.15**	0.42	0.23
$\rho = \rho_4$	16	16	14	14	6.1	15	7.4	7.6	**1.5**	1.6	2.2	1.8
$\rho = \rho_5$	65	66	46	25	50	24	16	17	9	8.5	8.9	**8.5**
$\rho = \rho_1$	0.32	0.26	0.33	0.31	0.32	0.25	0.24	0.25	0.2	0.19	0.2	**0.19**
$\rho = \rho_2$	0.33	0.26	0.34	0.32	0.33	0.25	0.25	0.25	0.2	0.19	0.19	**0.18**
$\rho = \rho_3$	1.2	1.1	1.2	1.2	1.2	1.2	1.2	1.1	**1**	1	1.2	1.2
$\rho = \rho_4$	3.3	3.3	3.5	3.1	2.8	3	1.6	**1.6**	3.7	3.5	3.2	3.3
$\rho = \rho_5$	19	19	19	16	20	15	12	**12**	22	22	18	18

Table 15: Vid. 8 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.264	1.47	0.985	1.1	1	1.62	1.06	1.04	3.57	**4.68**	3.51	4.33
$\rho = \rho_2$	0.268	1.47	0.959	1.1	1	1.62	1.46	1.39	3.24	**4.27**	3.22	4.01
$\rho = \rho_3$	8.57	0.999	1.05	1.09	1	1.09	2.35	2.23	27.5	**58.8**	20.5	36.7
$\rho = \rho_4$	16.1	0.993	1.13	1.11	2.65	1.1	2.16	2.12	**10.6**	10.2	7.19	8.98
$\rho = \rho_5$	65.4	0.994	1.41	2.66	1.3	2.7	4.2	3.84	7.29	7.71	7.31	**7.72**
$\rho = \rho_1$	0.323	1.25	0.975	1.04	1	1.31	1.36	1.31	1.63	1.73	1.66	**1.74**
$\rho = \rho_2$	0.335	1.28	0.999	1.05	1	1.34	1.33	1.33	1.67	1.8	1.75	**1.82**
$\rho = \rho_3$	1.17	1.06	0.978	0.969	1	1.02	0.981	1.04	**1.16**	1.11	1	0.991
$\rho = \rho_4$	3.34	1.02	0.947	1.09	1.19	1.11	2.08	**2.13**	0.911	0.945	1.04	1
$\rho = \rho_5$	19.2	1	1.01	1.23	0.96	1.24	1.6	**1.61**	0.883	0.868	1.05	1.04

Table 16: Vid. 8 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 9

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.14	0.069	0.17	0.14	0.14	0.068	0.35	0.33	0.037	**0.035**	0.038	0.036
$\rho = \rho_2$	0.14	0.094	0.29	0.14	0.14	0.094	5.9	5.7	**0.049**	0.051	0.05	0.051
$\rho = \rho_3$	2	2	1.6	0.44	1.8	0.43	5.4	5.1	0.29	0.24	0.21	**0.11**
$\rho = \rho_4$	12	12	10	7.2	11	**6.4**	11	11	7.5	7.1	6.6	6.4
$\rho = \rho_5$	18	18	14	6.1	11	5.7	8.8	8.6	7.4	7	4.2	**3.8**
$\rho = \rho_1$	0.18	0.17	0.25	0.18	0.18	0.17	0.23	0.21	0.15	0.15	0.15	**0.15**
$\rho = \rho_2$	0.21	0.22	0.23	0.21	0.21	0.22	1.2	1	0.18	0.2	**0.18**	0.2
$\rho = \rho_3$	4.4	4.4	4.4	**1.1**	4.3	1.1	4.2	2.6	2.9	2.7	1.5	1.4
$\rho = \rho_4$	12	12	12	4.6	12	**4.2**	13	12	13	14	7.6	8
$\rho = \rho_5$	13	13	13	4	13	**3.7**	11	9.4	15	15	9.6	9.8

Table 17: Vid. 9 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.138	2	0.808	1	1	2.05	0.392	0.425	3.78	**3.92**	3.68	3.88
$\rho = \rho_2$	0.142	1.5	0.491	1	1	1.5	0.024	0.0247	**2.87**	2.79	2.83	2.78
$\rho = \rho_3$	2	1	1.23	4.53	1.09	4.62	0.367	0.389	6.86	8.33	9.36	**17.6**
$\rho = \rho_4$	11.7	1.01	1.12	1.63	1.02	**1.83**	1.09	1.1	1.55	1.63	1.76	1.82
$\rho = \rho_5$	18.4	0.993	1.29	3.01	1.67	3.24	2.09	2.14	2.49	2.64	4.41	**4.81**
$\rho = \rho_1$	0.183	1.06	0.72	1	1	1.07	0.794	0.866	1.19	1.2	1.19	**1.2**
$\rho = \rho_2$	0.214	0.972	0.931	1	1	0.972	0.182	0.209	1.2	1.08	**1.2**	1.08
$\rho = \rho_3$	4.39	0.997	1	**4.12**	1.02	4.01	1.05	1.67	1.54	1.65	3.02	3.05
$\rho = \rho_4$	11.6	0.987	0.993	2.55	0.999	**2.79**	0.898	0.94	0.912	0.859	1.52	1.46
$\rho = \rho_5$	12.6	0.99	1	3.17	0.984	**3.43**	1.14	1.34	0.813	0.833	1.31	1.28

Table 18: Vid. 9 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 10

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.09	0.059	0.085	0.074	0.09	0.053	0.08	0.079	**0.045**	0.047	0.046	0.048
$\rho = \rho_2$	0.09	0.064	0.085	0.075	0.09	0.056	0.25	0.25	**0.05**	0.051	0.051	0.052
$\rho = \rho_3$	9	9	8.8	8.4	9	8.4	8.3	8.4	0.063	**0.062**	0.064	0.063
$\rho = \rho_4$	20	20	20	19	20	19	12	12	0.51	**0.48**	0.53	0.54
$\rho = \rho_5$	21	21	21	21	21	21	14	14	0.8	0.78	**0.55**	0.56
$\rho = \rho_1$	0.18	0.13	0.17	0.15	0.18	0.13	0.13	0.14	0.12	0.12	**0.12**	0.12
$\rho = \rho_2$	0.18	0.15	0.17	0.15	0.18	0.14	0.14	0.15	0.13	0.13	**0.12**	0.13
$\rho = \rho_3$	0.49	0.46	0.48	0.46	0.49	0.45	0.41	**0.41**	0.58	0.73	0.6	0.82
$\rho = \rho_4$	1.9	1.9	2.1	1.8	1.9	1.8	**0.79**	0.95	3.4	3.4	4	3.7
$\rho = \rho_5$	2.2	2.2	2.4	2.2	2.2	2.2	**1.4**	1.6	3.7	3	4	3.8

Table 19: Vid. 10 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.0897	1.53	1.06	1.21	1	1.69	1.12	1.13	**1.99**	1.91	1.95	1.89
$\rho = \rho_2$	0.0897	1.39	1.05	1.19	1	1.6	0.355	0.358	**1.8**	1.75	1.78	1.73
$\rho = \rho_3$	8.98	1	1.03	1.07	1	1.07	1.08	1.07	142	**144**	141	144
$\rho = \rho_4$	20.2	1	1.02	1.08	1.02	1.09	1.69	1.69	39.8	**41.8**	38	37.5
$\rho = \rho_5$	21.4	1	1.03	1	1.01	1	1.57	1.57	26.9	27.4	**39**	38.2
$\rho = \rho_1$	0.179	1.37	1.06	1.18	1	1.42	1.39	1.28	1.52	1.51	**1.55**	1.53
$\rho = \rho_2$	0.183	1.23	1.08	1.19	1	1.28	1.29	1.22	1.44	1.41	**1.47**	1.43
$\rho = \rho_3$	0.491	1.07	1.03	1.07	1	1.09	1.21	**1.21**	0.849	0.671	0.819	0.596
$\rho = \rho_4$	1.93	1	0.933	1.09	1	1.1	**2.44**	2.03	0.566	0.574	0.488	0.521
$\rho = \rho_5$	2.17	1	0.914	1	1	1	**1.56**	1.35	0.59	0.72	0.54	0.57

Table 20: Vid. 10 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 11

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.076	0.056	0.087	0.061	0.076	**0.053**	1.6	1.6	0.056	0.064	0.055	0.063
$\rho = \rho_2$	0.075	0.056	0.068	0.058	0.075	**0.052**	1.5	1.5	0.053	0.063	0.054	0.063
$\rho = \rho_3$	0.077	0.056	0.069	0.057	0.077	**0.051**	1.6	1.6	0.052	0.062	0.052	0.062
$\rho = \rho_4$	5.1	5.1	4.8	4.4	5.1	4.4	4.9	4.9	**0.66**	0.69	0.71	0.7
$\rho = \rho_5$	8.7	8.7	7.4	3	8.7	2.9	3.8	3.7	**0.24**	0.29	0.3	0.29
$\rho = \rho_1$	0.27	0.27	0.27	0.26	0.27	0.26	0.55	0.53	0.26	0.26	**0.26**	0.26
$\rho = \rho_2$	0.27	0.27	0.27	**0.26**	0.27	0.26	0.53	0.52	0.26	0.26	0.26	0.26
$\rho = \rho_3$	0.27	0.27	0.26	0.26	0.27	0.26	0.53	0.51	0.26	0.26	**0.26**	0.26
$\rho = \rho_4$	2.5	2.5	2.6	2.2	2.5	2.3	1.9	**1.9**	2.8	2.8	2.6	2.6
$\rho = \rho_5$	2.8	2.8	3	1.9	2.8	1.9	1.4	**1.4**	3	2.9	2.5	2.5

Table 21: Vid. 11 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.076	1.35	0.871	1.24	1	**1.44**	0.0465	0.0467	1.35	1.18	1.37	1.2
$\rho = \rho_2$	0.0745	1.33	1.09	1.28	1	**1.44**	0.0483	0.0486	1.4	1.18	1.39	1.18
$\rho = \rho_3$	0.0775	1.39	1.12	1.37	1	**1.51**	0.0473	0.0476	1.48	1.24	1.48	1.25
$\rho = \rho_4$	5.07	0.995	1.05	1.16	1	1.14	1.03	1.04	**7.7**	7.36	7.12	7.28
$\rho = \rho_5$	8.69	0.996	1.18	2.92	1	2.97	2.27	2.33	**35.6**	29.7	28.5	29.9
$\rho = \rho_1$	0.273	1.02	1.02	1.04	1	1.05	0.497	0.511	1.04	1.05	**1.06**	1.06
$\rho = \rho_2$	0.273	1.02	1.02	**1.05**	1	1.05	0.512	0.526	1.04	1.04	1.04	1.04
$\rho = \rho_3$	0.273	1.02	1.03	1.05	1	1.05	0.513	0.529	1.05	1.05	**1.06**	1.05
$\rho = \rho_4$	2.51	1.01	0.973	1.12	1	1.12	1.3	**1.31**	0.904	0.901	0.96	0.964
$\rho = \rho_5$	2.82	1.01	0.945	1.49	0.999	1.49	2.07	**2.08**	0.946	0.977	1.14	1.12

Table 22: Vid. 11 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Video 12

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.11	0.1	0.1	0.082	0.11	0.07	0.86	0.95	0.072	**0.069**	0.072	0.07
$\rho = \rho_2$	0.12	0.13	0.11	0.08	0.12	0.07	0.85	0.86	**0.053**	0.054	0.053	0.055
$\rho = \rho_3$	7	7	6.4	6.5	8	6.5	7	7	3.1	**3**	5.8	5.8
$\rho = \rho_4$	12	12	10	7.6	9.5	7.7	11	11	5.8	5.7	5.4	**5.2**
$\rho = \rho_5$	17	18	14	8	12	8.1	11	11	8.6	8.6	7.4	**7.2**
$\rho = \rho_1$	0.21	0.27	0.19	0.18	0.21	0.24	0.81	0.73	0.17	0.17	0.17	**0.17**
$\rho = \rho_2$	0.21	0.28	0.2	0.18	0.21	0.24	0.8	0.71	0.17	0.18	**0.17**	0.18
$\rho = \rho_3$	6.2	6.2	6.3	5.8	6.3	5.8	6	6	6.6	7	5.5	**5.3**
$\rho = \rho_4$	12	13	12	**4.5**	12	4.7	15	14	15	14	7.1	8.1
$\rho = \rho_5$	15	15	15	3.6	14	**3.5**	12	11	18	17	8.5	8.5

Table 23: Vid. 12 absolute RMS positional (top 5 rows) and orient. error (bottom 5 rows).

	A	B	C	D	E	F	G	H	I	J	K	L
$\rho = \rho_1$	0.113	1.09	1.09	1.38	1	1.62	0.131	0.119	1.57	**1.62**	1.56	1.61
$\rho = \rho_2$	0.116	0.897	1.08	1.44	1	1.67	0.136	0.135	**2.18**	2.15	2.17	2.12
$\rho = \rho_3$	6.96	1	1.08	1.07	0.87	1.07	0.987	0.992	2.25	**2.29**	1.21	1.21
$\rho = \rho_4$	11.7	0.975	1.11	1.53	1.22	1.52	1.07	1.08	2.03	2.06	2.15	**2.24**
$\rho = \rho_5$	17.3	0.984	1.23	2.16	1.4	2.12	1.61	1.62	2	2	2.33	**2.39**
$\rho = \rho_1$	0.208	0.779	1.07	1.19	1	0.881	0.258	0.287	1.19	1.22	1.22	**1.23**
$\rho = \rho_2$	0.213	0.761	1.09	1.19	1	0.881	0.266	0.299	1.25	1.2	**1.28**	1.2
$\rho = \rho_3$	6.19	0.991	0.98	1.08	0.982	1.07	1.02	1.03	0.931	0.888	1.13	**1.16**
$\rho = \rho_4$	12.4	0.986	0.996	**2.79**	1	2.64	0.84	0.861	0.83	0.894	1.76	1.54
$\rho = \rho_5$	15.1	0.992	0.999	4.23	1.05	**4.32**	1.28	1.32	0.861	0.871	1.76	1.78

Table 24: Vid. 12 relative improvement of Col. B:L to baseline Col. A. Top 5 rows: improvement in positional error, Bottom 5 rows: improvement in orientational error.

Comparison to registration after SFM

In order to compare our trajectory refinement methods with standard Structure from Motion (SfM) pose estimates we reconstructed each video individually with publicly available SfM tools[3]. We manually (rigidly) aligned and scaled the resulting 3D model and camera poses to fit the GT camera poses. Finally, we used non-linear least squares to refine the alignment and scale by minimizing the RMS (root mean squared) positional error of the SfM camera trajectory. The positional errors for all SfM camera pose trajectories are shown in table 25. For videos 2,3 and 6 the SfM procedure produced several models, which we aligned separately. The ground truth camera camera trajectories and SfM trajectories are plotted together in table 26.

	V01	V02	V03	V04	V05	V06	V07	V08	V09	V10	V11	V12	∅
RMS, $\rho = \rho_5$	7.62	0.99	**5.26**	0.11	**0.53**	5.06	6.62	20.04	**1.59**	32.19	28.27	**0.3339**	9.05

Table 25: RMS positional error of SFM pose estimates after manual alignment with GT for all 12 videos. Numbers in bold indicate better result than our best trajectory smoothing method.

We notice that the SfM approach results in overall best registration results in 4 out of 12 videos for $\rho = \rho_5$ (i.e. without filtering out pose outliers). However, this included significant manual alignment work at the end. On average the RMS positional error of 9.05 meters is significantly worse than the best result achieved by our method (LS+CP, 2.267 meters). See left table in Fig. 4 of the paper.

We notice that registration with SfM leads to several severe problems:

1. The SfM procedure might fail to produce one single 3D model. In the case of multiple models, manual stitching is required.
2. The SfM procedure may lead to significant model distortions because scale and positional accuracy are difficult to enforce over longer reconstructed sequences.
3. The SfM procedure may link images incorrectly because of potential problems in feature matching, essential matrix computation, or iterative next-best-view selection. Furthermore, several possible degenerate cases (i.e. zero movement) will lead to failure in reconstruction.
4. The SfM procedure is time consuming in comparison to our pose refinement.
5. Because the SfM procedure cannot recover the scale, absolute position and orientation, manual (rigid) alignment to a world model is needed at the end.

Due to these reasons and the bad average registration success, we argue that reconstructing first and subsequent alignment is not a good alternative to trajectory smoothing.

[3] Visual SfM: http://ccwu.me/vsfm/

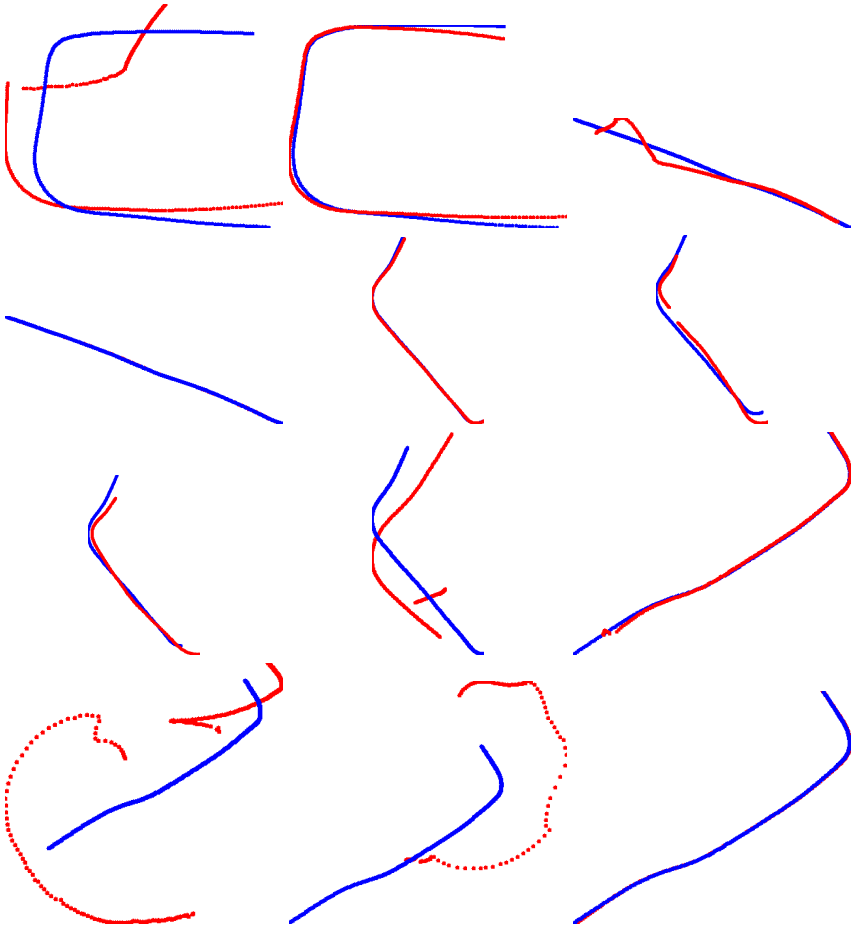

Table 26: GT pose trajectories in blue. SfM pose trajectories (in red) after rigid alignment with GT by minimization of RMS positional error. Notice that model distortions make reliable alignment very difficult for most video sequences. Ordering of videos: 1 to 12 from left to right, and top to bottom.