Supplemental Material for Efficient Map Sparsification Based on 2D and 3D Discretized Grids

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1. Overview

In this supplemental material, we provide more experimental results and analysis. 1) We compare localization in original maps and compact maps, showing the superiority in memory consumption and localization efficiency for using compact maps. 2) We provide more experimental results of localizing different spatial distributed query images in compact maps acquired by different methods. 3) We provide more experimental results of run-time and memory consumption. 4) We provide more visualization of compact maps compared with original maps.

2. Localization in Compact Map

Compact maps are compared with original maps for localization. Several representative results are shown in Tab. 1, in which original maps contain various numbers of landmarks.

The most memory-consuming part in a map is the descriptors of landmarks. Therefore, as the number of landmarks decreases in compact maps, consumed memory is also reduced largely. Besides, localizing in compact maps becomes much faster than in original ones, since less landmarks are searched to match with features of query images. In sequence 02, for example, the compact map takes up only 3.13% of the memory compared with the original map, and the localization in the compact map runs more than 5 times faster.

This comparison demonstrates the superiority and benefits of using compact maps for localization, especially when an original map is very large.

3. Map Sparsification Based on 2D and 3D Grids

More experimental results of localizing different spatial distributed query images in compact maps are shown in Tab. 2. Compact maps are acquired by different map sparsification methods, including LP, QP1, and QP2. These methods get comparable localization results with Ours-2D. Ours-3D still gets the highest localization rate for most testings because of involving 3D space constraints.

4. Comparison Experiments

More results of the comparison of different map sparsification methods in terms of run-time and memory consumption are provided in Tab. 3 and Tab. 4. The proposed method is much more efficient than QP.

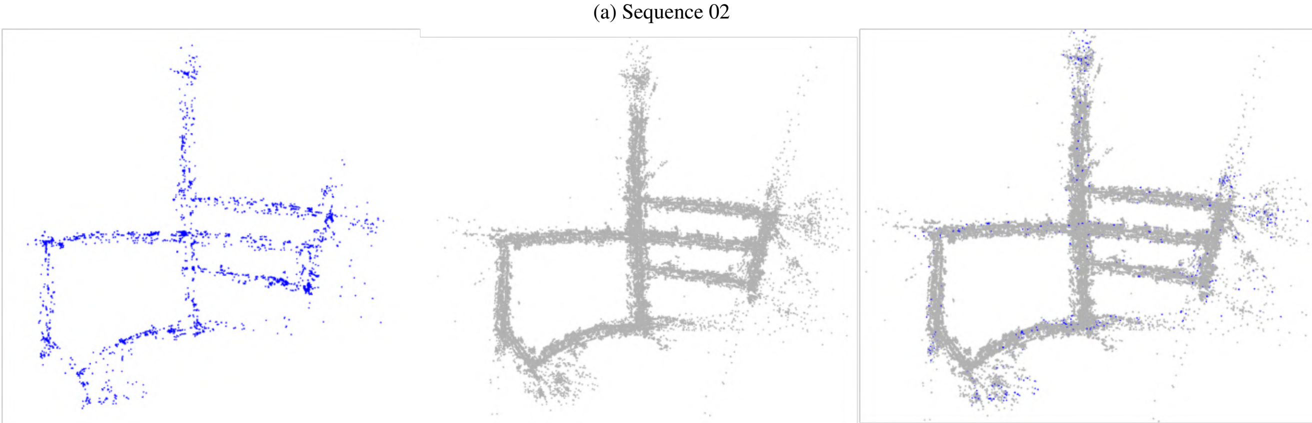
5. Visualization

Compact and original maps are drawn in different colors in Fig. 1. Compared with original maps, the landmarks in compact maps are much more sparse and they spread throughout whole space, providing comparable localization results for query images.

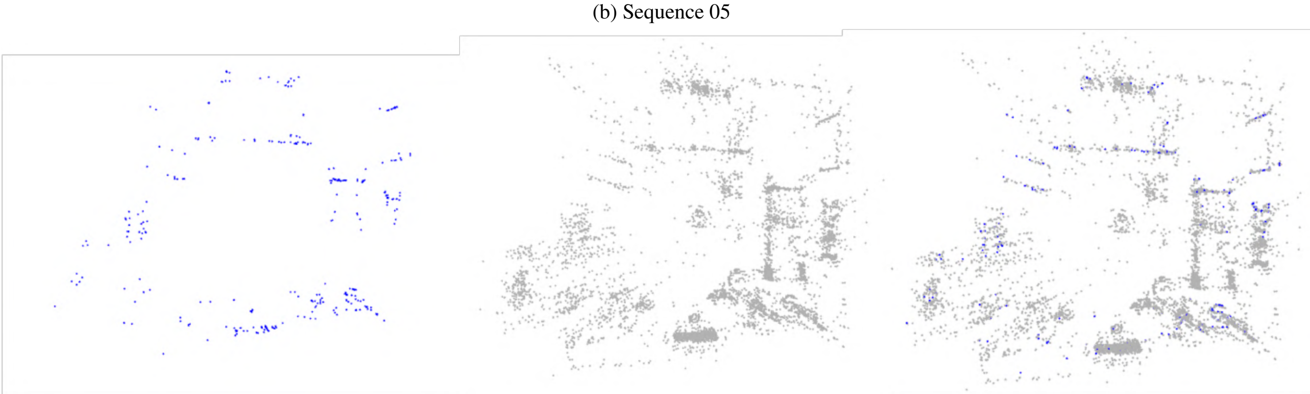
Table 1. Comparison of localization in original and compact maps. N denotes the number of landmarks, S denotes the used memory for storing the map, and t denotes the average run-time for localizing a query image.

Seq.	Original Map				Compact Map			
	N	N_k	S (MB)	t (ms)	N	N_k	S (MB)	t (ms)
liv0	4061	107	5.37	33.54	520	107	0.49	20.75
off0	5875	133	11.08	48.19	398	133	0.69	24.01
V103	11518	216	15.70	67.11	1141	216	0.96	43.48
MH5	16956	369	29.45	89.83	1118	369	1.94	45.38
07	27036	258	34.55	115.95	1241	258	1.07	65.89
09	55984	603	80.44	172.88	2945	603	2.50	68.01
08	119323	1269	169.47	292.50	5902	1269	5.36	71.86
02	182499	1794	240.13	377.38	7661	1794	7.51	70.08

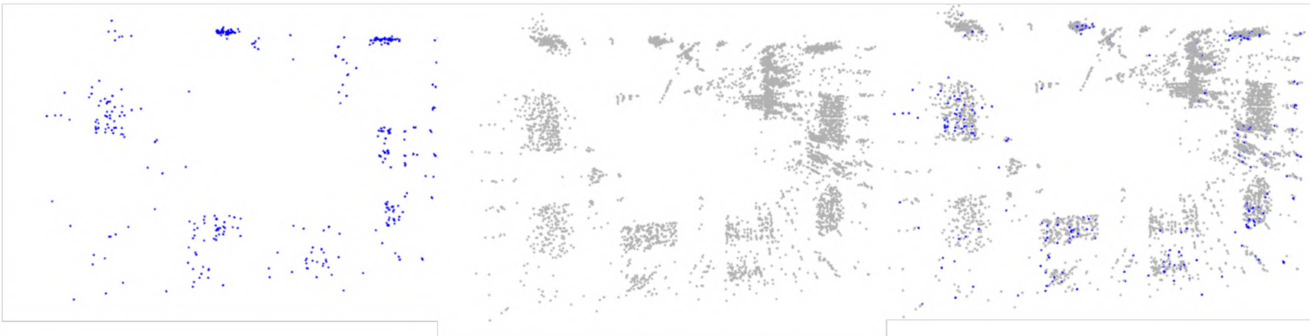
(a) Sequence 02



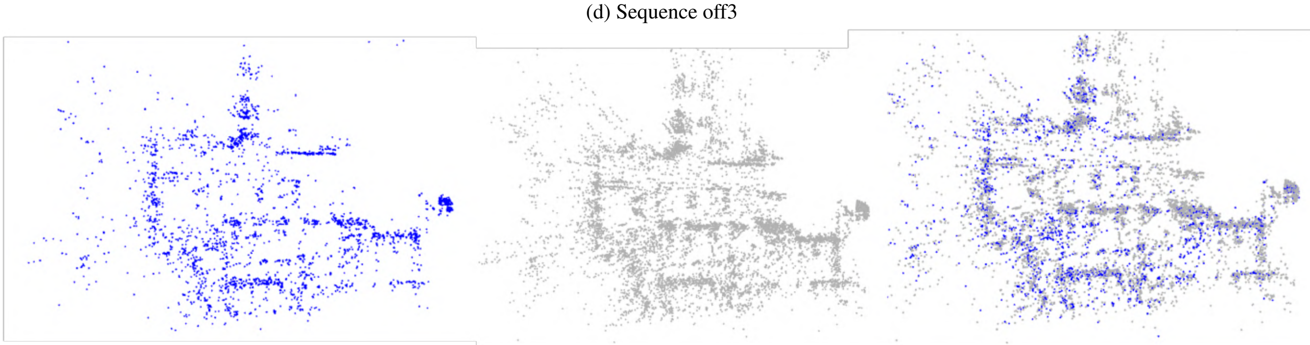
(b) Sequence 05



(c) Sequence liv2

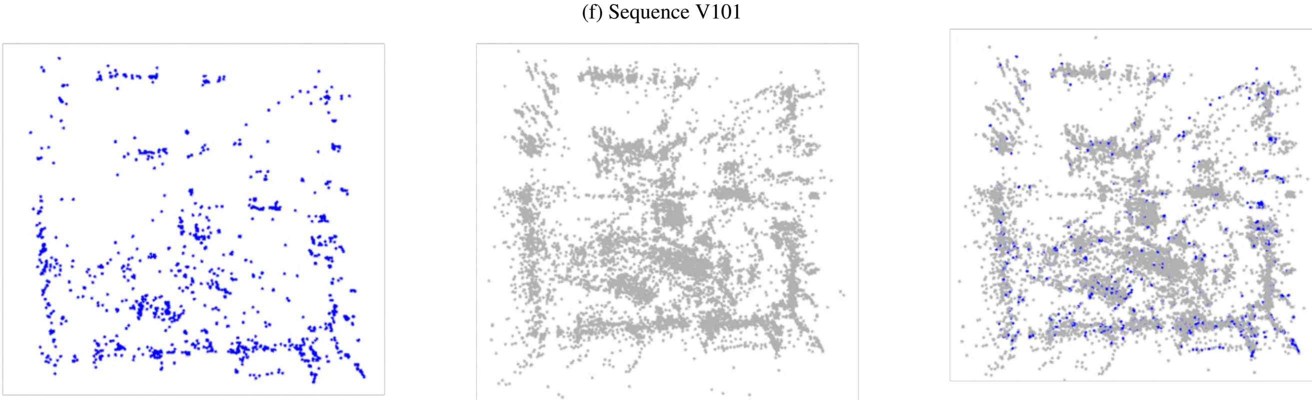


(d) Sequence off3



(e) Sequence MH1

(f) Sequence V101



(g) Sequence V202

Figure 1. Illustration of compact and original maps. The first column shows compact maps in blue; the second column shows original maps in gray; and compact and original maps are drawn together in the third column.

Table 2. Comparison of different map sparsification methods in terms of localization rate. Num denotes the number of landmarks in the map, Rate denotes the localization rate in the corresponding map. The sequence for mapping is indicated in bold and the images from several different sequences are localized in the map. The highest localization rates in compact maps are labelled in bold.

	off0				**off2**			**liv2**		
Map	Num	Rate off0	Rate off2	Rate off3	Num	Rate off0	Rate off2	Num	Rate liv1	Rate liv2
Original	5875	99.93%	66.70%	52.26%	6838	65.65%	100.00%	6435	55.80%	100.00%
Ours-2D	398	95.62%	27.95%	7.74%	299	4.31%	**92.27%**	312	2.48%	**91.36%**
Ours-3D	399	95.49%	**28.52%**	**7.98%**	301	**6.17%**	91.70%	314	**4.04%**	90.68%
LP	398	95.42%	27.50%	7.34%	298	4.38%	91.02%	310	3.93%	89.77%
QP1	398	**95.76%**	27.27%	7.42%	298	3.51%	90.34%	310	3.00%	90.57%
QP2	398	**95.76%**	28.18%	7.74%	298	3.38%	91.36%	310	2.59%	91.02%

	MH1				**MH4**			**MH5**		
Map	Num	Rate MH1	Rate MH2	Rate MH3	Num	Rate MH4	Rate MH5	Num	Rate MH4	Rate MH5
Original	12506	99.04%	87.10%	52.53%	17490	99.69%	84.20%	16956	82.34%	99.77%
Ours-2D	2978	**97.33%**	73.67%	45.76%	744	**97.37%**	63.77%	1116	74.75%	**98.87%**
Ours-3D	2982	96.78%	**73.97%**	**46.18%**	745	97.06%	**64.27%**	1121	**75.71%**	98.74%
LP	2976	97.03%	72.83%	46.10%	743	97.32%	63.46%	1116	74.75%	98.69%
QP1	2976	96.76%	72.33%	45.57%	742	97.27%	63.19%	1116	72.20%	98.60%
QP2	2977	96.54%	71.87%	45.72%	742	97.01%	64.04%	1116	74.14%	98.60%

	MH2				**V101**			**V102**		
Map	Num	Rate MH1	Rate MH2	Rate MH3	Num	Rate V101	Rate V102	Num	Rate V101	Rate V102
Original	11306	91.78%	99.73%	51.81%	6864	99.03%	61.56%	9878	72.25%	98.12%
Ours-2D	2546	74.80%	98.17%	35.50%	461	86.04%	32.60%	507	34.61%	85.93%
Ours-3D	2550	**77.41%**	97.77%	38.69%	462	85.79%	**34.61%**	506	**37.67%**	**85.99%**
LP	2544	75.57%	96.43%	37.86%	460	84.92%	32.35%	507	34.61%	84.86%
QP1	2547	76.72%	**98.33%**	**39.11%**	461	85.52%	32.16%	506	34.16%	85.87%
QP2	2547	76.81%	98.30%	38.62%	461	**86.35%**	32.66%	506	33.25%	85.49%

	MH3				**V201**			**V202**		
Map	Num	Rate MH1	Rate MH2	Rate MH3	Num	Rate V201	Rate V202	Num	Rate V201	Rate V202
Original	15234	59.93%	52.80%	97.34%	7346	94.69%	52.77%	11791	75.22%	99.48%
Ours-2D	2105	46.85%	37.23%	95.32%	565	79.64%	19.48%	1254	49.82%	93.25%
Ours-3D	2108	46.94%	**37.60%**	95.25%	569	**80.00%**	**22.77%**	1256	50.04%	**93.46%**
LP	2104	**47.16%**	37.30%	95.32%	564	78.75%	20.26%	1254	**50.27%**	92.86%
QP1	2107	46.74%	36.90%	**95.44%**	564	78.62%	20.26%	1254	49.73%	93.07%
QP2	2105	47.05%	37.37%	95.17%	564	78.97%	19.18%	1254	49.64%	93.42%

Table 3. Comparison of different map sparsification methods in terms of run-time. N denotes the number of landmarks, N_k denotes the number of keyframes.

Seq.	Original Map		Run-time (s)				
	N	N_k	Ours	LP	QP1	QP2	DI
liv0	4.1K	107	0.2	0.1	13.6	12.5	0.2
liv1	4.1K	49	0.2	0.1	16.2	14.7	0.1
liv2	6.4K	78	0.3	0.1	66.0	22.4	0.2
liv3	6.2K	121	0.3	0.1	28.9	21.6	0.2
off0	5.9K	133	0.3	0.1	27.9	18.9	0.2
off1	6.0K	46	0.1	0.1	29.7	25.7	0.1
off2	6.8K	66	0.2	0.1	39.9	28.7	0.2
off3	5.4K	37	0.1	0.1	49.5	39.3	0.1
MH1	12.5K	483	1.0	0.3	49.6	25.5	0.6
MH2	11.3K	428	1.0	0.3	42.8	29.3	0.6
MH3	15.2K	468	1.6	0.5	78.5	52.2	1.1
MH4	17.5K	314	10.0	7.1	127	182	1.4
MH5	17.0K	369	4.5	2.2	107	61.5	1.2
V101	6.9K	107	1.1	0.2	20.9	16.9	0.3
V102	9.9K	148	0.8	0.3	49.4	31.1	0.4
V103	11.5K	216	1.1	0.3	59.8	36.3	0.6
V201	7.3K	109	0.3	0.1	30.3	20.8	0.3
V202	11.8K	273	2.6	1.3	56.6	31.8	0.6
V203	14.6K	294	0.8	0.2	41.8	31.7	0.9
00	142K	1458	157	169	-	-	9.9
01	89.4K	1064	16.9	30.6	-	-	5.5
02	182K	1794	69.6	63.2	-	-	7.9
03	24.3K	217	2.6	1.1	110	71.5	0.6
04	16.8K	163	2.4	2.6	89.8	143	0.6
05	74.2K	758	65.9	45.7	-	-	3.2
06	42.5K	492	10.9	27.5	376	395	2.2
07	27.0K	258	2.6	1.1	127	95.5	0.7
08	119K	1269	33.2	19.2	-	-	4.9
09	56.0K	603	7.7	9.9	754	491	1.8
10	30.9K	346	3.3	1.3	94.4	143.2	0.9

Table 4. Comparison of different map sparsification methods in terms of memory consumption. N denotes the number of landmarks, N_k denotes the number of keyframes.

Seq.	Original Map		Consumed Memory (MB)				
	N	N_k	Ours	LP	QP1	QP2	DI
liv0	4.1K	107	35	14	555	476	33
liv1	4.1K	49	66	27	755	971	31
liv2	6.4K	78	52	24	2286	770	26
liv3	6.2K	121	73	14	1061	754	37
off0	5.9K	133	61	27	842	708	21
off1	6.0K	46	33	11	1718	1697	19
off2	6.8K	66	87	25	1387	857	40
off3	5.4K	37	19	12	1065	1158	31
MH1	12.5K	483	115	63	1612	862	64
MH2	11.3K	428	116	40	1573	899	49
MH3	15.2K	468	129	37	2226	1418	74
MH4	17.5K	314	391	193	6097	4624	130
MH5	17.0K	369	255	107	3532	1656	77
V101	6.9K	107	92	36	1338	662	21
V102	9.9K	148	126	56	1901	1065	27
V103	11.5K	216	128	56	3048	1367	83
V201	7.3K	109	97	55	1774	754	28
V202	11.8K	273	174	81	2964	1180	80
V203	14.6K	294	138	66	2080	1294	52
00	142K	1458	2404	818	-	-	726
01	89.4K	1064	2046	778	-	-	567
02	182K	1794	3494	1502	-	-	1187
03	24.3K	217	338	97	5131	3218	58
04	16.8K	163	279	66	3906	2957	93
05	74.2K	758	436	363	-	-	274
06	42.5K	492	732	208	14527	4812	234
07	27.0K	258	141	62	6315	5766	100
08	119K	1269	1162	637	-	-	512
09	56.0K	603	676	230	13005	10952	211
10	30.9K	346	355	113	7027	2989	92