Supplementary Materials
APA Light Field denoising

We present supplementary materials for our paper "Light Field Denoising via Anisotropic Parallax Analysis in a CNN Framework". Content contained in this documents are:

1) Section I gives details of the testing and training dataset we used.
2) Section II gives detailed quantitative evaluation result for each testing data, under different noise levels. Results for different competing methods as well as baseline methods are also presented.
3) Section III gives more visual comparisons.

I. Training and Testing Dataset Details

A. The Testing Dataset

The testing dataset consists of 30 LF images randomly chosen from 5 categories of the Stanford Lytro Light Field Archive [1].

Category 'bikes'	'bikes_2', 'bikes_3', 'bikes_4', 'bikes_5', 'bikes_6';
Category 'buildings'	'buildings_21', 'buildings_22', 'buildings_23', 'buildings_24', 'buildings_25';
Category 'cars'	'cars_21', 'cars_22', 'cars_23', 'cars_24', 'cars_25';
Category 'flowers_plants'	'flowers_plants_21', 'flowers_plants_22', 'flowers_plants_23', 'flowers_plants_24', 'flowers_plants_25';
Category 'fruits_vegetables'	'fruits_vegetables_2', 'fruits_vegetables_3', 'fruits_vegetables_4', 'fruits_vegetables_5', 'fruits_vegetables_6'
Category 'people'	'people_5', 'people_6', 'people_7', 'people_8', 'people_9'

B. The Training Dataset

The training dataset consists of 70 LF images randomly chosen from 6 categories of the Stanford Lytro Light Field Archive [1].

Category 'bikes'	'bikes_10', 'bikes_11', 'bikes_12', 'bikes_13', 'bikes_14', 'bikes_15', 'bikes_16', 'bikes_17', 'bikes_18', 'bikes_19';
Category 'buildings'	'buildings_10', 'buildings_11', 'buildings_12', 'buildings_13', 'buildings_14', 'buildings_15', 'buildings_16', 'buildings_17', 'buildings_18', 'buildings_19';
Category 'cars'	'cars_10', 'cars_11', 'cars_12 'cars_13', 'cars_14', 'cars_15', 'cars_16', 'cars_17', 'cars_18', 'cars_19';
Category 'flowers_plants'	'flowers_plants_10', 'flowers_plants_11', 'flowers_plants_12', 'flowers_plants_13', 'flowers_plants_14', 'flowers_plants_15', 'flowers_plants_16', 'flowers_plants_17', 'flowers_plants_18', 'flowers_plants_19';
Category 'fruits_vegetables'	'fruits_vegetables_10', 'fruits_vegetables_11', 'fruits_vegetables_12', 'fruits_vegetables_13', 'fruits_vegetables_14', 'fruits_vegetables_15', 'fruits_vegetables_16', 'fruits_vegetables_17', 'fruits_vegetables_18', 'fruits_vegetables_19';
Category 'people'	'people_1', 'people_2', 'people_10', 'people_11', 'people_12', 'people_13', 'people_14', 'people_15', 'people_16', 'people_17';
Category 'general'	'general_10', 'general_11', 'general_12', 'general_13', 'general_14', 'general_15', 'general_16', 'general_17', 'general_18', 'general_19';

II. Detailed Quantitative Evaluation Result for Each Testing Data

In our submitted paper, due to space limitation, only the average value for the testing dataset is given. In this section, detailed quantitative evaluation results are given for each testing data.

III. More Visual Comparisons

We give more visual comparisons on the denoising results in this section. Specifically, 6 more visual comparisons are given for the noise level $\sigma = 50$ (higher noise level show more obvious visual differences after denoising), and 3 more comparisons for $\sigma = 20$, and 2 more for $\sigma = 10$, respectively. The $(4, 4)^{th}$ SAI is shown for each LF. PSNR for each denoised LF is shown at the top left of each image. Digital zoom-in is suggested for detail comparison.

References

[1] *Stanford Lytro Light Field Archive*, Available at http://lightfields.stanford.edu/index.html.

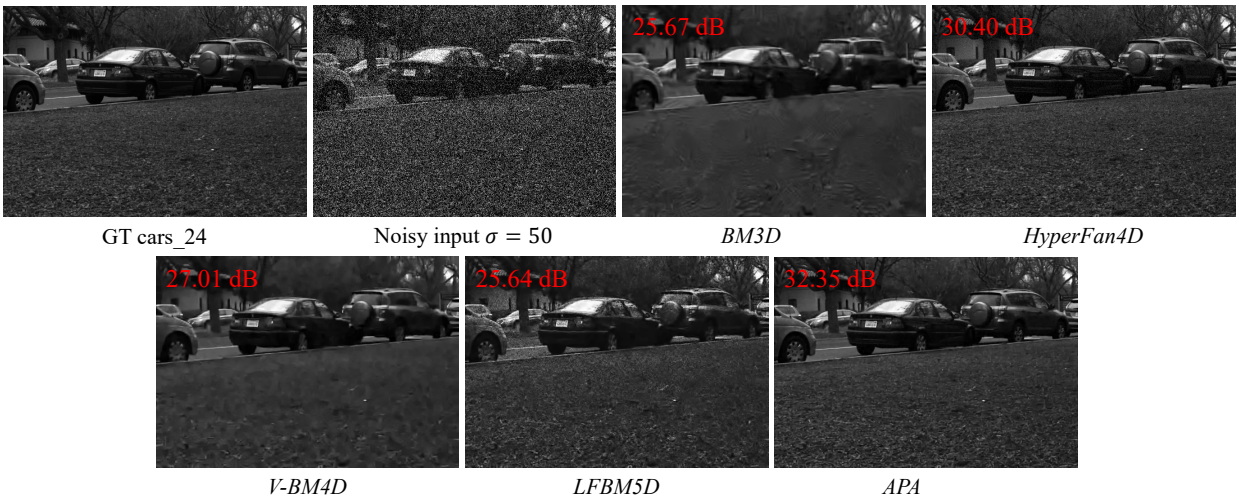

Fig. 1: Visual comparison between different denoisers for the testing LF data “cars_24” at noise level $\sigma = 50$.

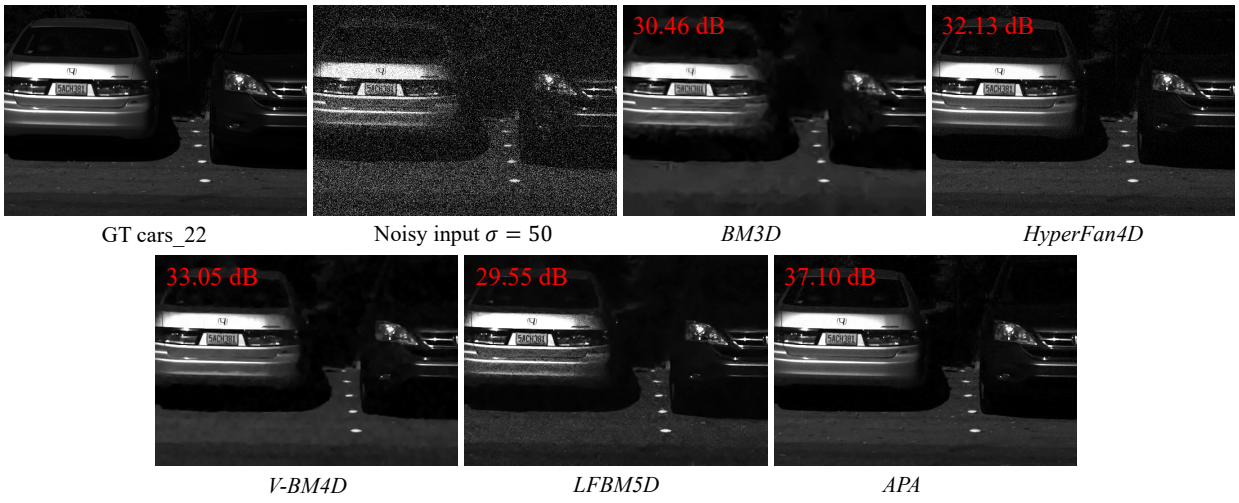

Fig. 2: Visual comparison between different denoisers for the testing LF data “cars_22” at noise level $\sigma = 50$.

TABLE I: LF Denoising results for the testing dataset at noise level $\sigma = 10$. Each result entry is in the format of PSNR (dB)/ SSIM.

Methods / Data		Avg-All	BM3D	HyperFan4D	V-BM4D	LFBM5D	APA-syn	APA
1	bikes_2	29.1/ 0.89	35.1/ 0.92	31.1/ 0.91	36.7/ 0.95	36.2/ 0.93	34.5/ 0.95	36.8/ 0.97
2	bikes_3	25.1/ 0.81	34.6/ 0.91	29.0/ 0.87	36.1/ 0.94	35.3/ 0.92	34.0/ 0.95	35.0/ 0.96
3	bikes_4	26.1/ 0.90	34.2/ 0.92	29.6/ 0.91	35.8/ 0.95	35.8/ 0.94	34.2/ 0.97	34.8/ 0.97
4	bikes_5	26.1/ 0.88	34.7/ 0.91	29.5/ 0.90	36.6/ 0.94	36.2/ 0.94	33.3/ 0.96	35.5/ 0.97
5	bikes_6	24.4/ 0.87	35.7/ 0.93	27.3/ 0.90	37.1/ 0.95	36.8/ 0.95	31.1/ 0.94	34.7/ 0.96
6	buildings_21	34.5/ 0.92	38.3/ 0.94	35.6/ 0.90	39.9/ 0.95	38.4/ 0.92	41.0/ 0.97	42.4/ 0.97
7	buildings_22	39.1/ 0.96	39.7/ 0.95	37.3/ 0.92	41.1/ 0.96	39.2/ 0.92	40.2/ 0.97	44.0/ 0.98
8	buildings_23	28.5/ 0.78	38.4/ 0.94	30.4/ 0.81	39.8/ 0.95	38.0/ 0.88	35.1/ 0.91	40.2/ 0.95
9	buildings_24	27.0/ 0.81	38.3/ 0.94	28.7/ 0.83	39.7/ 0.96	37.6/ 0.89	35.4/ 0.93	39.4/ 0.96
10	buildings_25	31.4/ 0.91	42.4/ 0.95	31.9/ 0.88	43.4/ 0.97	40.8/ 0.91	37.4/ 0.94	44.2/ 0.97
11	cars_21	29.5/ 0.89	35.5/ 0.92	32.1/ 0.90	37.4/ 0.95	36.5/ 0.92	36.8/ 0.96	37.8/ 0.97
12	cars_22	39.1/ 0.97	38.4/ 0.94	38.4/ 0.94	40.4/ 0.96	38.5/ 0.91	41.3/ 0.97	41.9/ 0.98
13	cars_23	41.1/ 0.97	40.7/ 0.94	39.8/ 0.93	42.8/ 0.96	41.5/ 0.93	43.8/ 0.97	44.9/ 0.98
14	cars_24	34.6/ 0.95	32.2/ 0.87	35.6/ 0.95	35.9/ 0.95	35.4/ 0.94	38.0/ 0.97	38.3/ 0.97
15	cars_25	36.0/ 0.96	33.0/ 0.89	36.4/ 0.96	36.5/ 0.95	35.7/ 0.94	38.4/ 0.97	38.8/ 0.98
16	flowers_plants_21	25.0/ 0.86	33.5/ 0.95	27.7/ 0.89	35.3/ 0.97	34.6/ 0.95	34.4/ 0.97	35.7/ 0.98
17	flowers_plants_22	31.3/ 0.90	36.8/ 0.93	33.3/ 0.90	39.0/ 0.95	36.7/ 0.92	38.3/ 0.97	40.9/ 0.97
18	flowers_plants_23	31.3/ 0.84	36.5/ 0.93	32.4/ 0.86	38.6/ 0.95	36.7/ 0.92	38.5/ 0.96	39.8/ 0.97
19	flowers_plants_24	27.7/ 0.76	35.3/ 0.91	29.4/ 0.83	37.2/ 0.94	35.7/ 0.92	35.2/ 0.94	37.4/ 0.95
20	flowers_plants_25	26.8/ 0.75	34.5/ 0.91	29.7/ 0.85	36.5/ 0.94	35.0/ 0.92	34.3/ 0.94	36.5/ 0.95
21	fruits_vegetables_2	28.3/ 0.84	35.3/ 0.93	29.8/ 0.87	37.9/ 0.96	36.1/ 0.93	36.0/ 0.96	38.4/ 0.97
22	fruits_vegetables_3	22.5/ 0.89	33.9/ 0.94	25.3/ 0.90	34.3/ 0.95	35.4/ 0.95	29.2/ 0.95	30.8/ 0.97
23	fruits_vegetables_4	27.3/ 0.89	36.1/ 0.93	29.4/ 0.90	37.8/ 0.95	36.5/ 0.93	33.6/ 0.96	37.2/ 0.97
24	fruits_vegetables_5	25.4/ 0.80	36.0/ 0.93	27.7/ 0.85	37.4/ 0.95	36.2/ 0.93	31.4/ 0.93	35.9/ 0.96
25	fruits_vegetables_6	26.2/ 0.85	35.7/ 0.92	28.3/ 0.87	37.2/ 0.95	36.1/ 0.93	31.9/ 0.94	35.5/ 0.96
26	people_5	28.8/ 0.90	35.9/ 0.93	29.4/ 0.88	38.4/ 0.95	37.0/ 0.93	35.0/ 0.95	39.1/ 0.97
27	people_6	34.8/ 0.93	36.8/ 0.93	35.7/ 0.92	38.6/ 0.94	37.0/ 0.91	38.8/ 0.95	40.0/ 0.96
28	people_7	38.7/ 0.96	44.4/ 0.98	37.8/ 0.91	45.5/ 0.98	40.6/ 0.92	41.6/ 0.98	45.7/ 0.98
29	people_8	37.8/ 0.95	37.6/ 0.92	37.5/ 0.92	39.3/ 0.94	37.7/ 0.91	41.1/ 0.97	42.4/ 0.97
30	people_9	33.5/ 0.90	36.2/ 0.89	35.6/ 0.91	37.7/ 0.91	36.3/ 0.88	39.3/ 0.95	40.2/ 0.96
Average		30.6/ 0.88	36.5/ 0.93	32.1/ 0.89	38.3/ 0.95	37.0/ 0.92	36.4/ 0.96	38.8/ 0.97

TABLE II: LF Denoising results for the testing dataset at noise level $\sigma = 20$. Each result entry is in the format of PSNR (dB)/ SSIM.

Methods / Data		Avg-All	BM3D	HyperFan4D	V-BM4D	LFBM5D	APA-syn	APA
1	bikes_2	28.8/ 0.86	31.4/ 0.86	29.8/ 0.83	33.3/ 0.90	32.5/ 0.86	33.6/ 0.94	35.0/ 0.95
2	bikes_3	25.0/ 0.77	30.8/ 0.85	28.1/ 0.78	32.9/ 0.89	31.4/ 0.84	33.4/ 0.94	33.6/ 0.94
3	bikes_4	26.0/ 0.86	30.1/ 0.85	28.6/ 0.83	32.2/ 0.89	31.6/ 0.87	33.3/ 0.95	33.5/ 0.96
4	bikes_5	26.0/ 0.85	31.0/ 0.83	28.5/ 0.82	32.8/ 0.88	32.3/ 0.87	32.7/ 0.94	33.7/ 0.95
5	bikes_6	24.3/ 0.84	32.0/ 0.87	26.7/ 0.82	33.5/ 0.90	32.9/ 0.89	30.8/ 0.93	32.0/ 0.94
6	buildings_21	33.7/ 0.87	35.2/ 0.90	32.7/ 0.77	36.9/ 0.92	34.7/ 0.84	39.6/ 0.96	40.4/ 0.96
7	buildings_22	36.7/ 0.91	36.6/ 0.93	33.4/ 0.77	38.2/ 0.94	35.2/ 0.84	39.1/ 0.97	41.5/ 0.97
8	buildings_23	28.3/ 0.74	34.9/ 0.88	29.4/ 0.69	36.4/ 0.91	34.6/ 0.80	34.6/ 0.90	37.8/ 0.92
9	buildings_24	26.9/ 0.77	34.8/ 0.90	27.9/ 0.71	36.4/ 0.92	33.9/ 0.80	35.0/ 0.92	37.0/ 0.93
10	buildings_25	30.9/ 0.84	39.5/ 0.92	30.7/ 0.73	40.5/ 0.94	37.3/ 0.84	37.1/ 0.94	41.8/ 0.94
11	cars_21	29.2/ 0.85	32.1/ 0.85	30.6/ 0.81	33.9/ 0.89	33.0/ 0.85	35.6/ 0.94	36.0/ 0.95
12	cars_22	37.0/ 0.92	35.0/ 0.90	34.5/ 0.81	37.3/ 0.92	34.3/ 0.81	39.6/ 0.96	39.7/ 0.96
13	cars_23	38.2/ 0.91	37.1/ 0.89	35.6/ 0.78	39.2/ 0.92	37.8/ 0.87	42.5/ 0.97	42.7/ 0.96
14	cars_24	33.8/ 0.93	28.8/ 0.73	32.8/ 0.90	31.5/ 0.83	30.9/ 0.84	35.7/ 0.95	36.0/ 0.95
15	cars_25	34.9/ 0.94	29.6/ 0.77	33.2/ 0.89	32.3/ 0.86	31.3/ 0.85	36.3/ 0.95	36.6/ 0.96
16	flowers_plants_21	24.9/ 0.84	29.5/ 0.89	27.0/ 0.84	31.7/ 0.93	31.0/ 0.92	33.4/ 0.96	33.8/ 0.96
17	flowers_plants_22	30.8/ 0.85	33.5/ 0.87	31.2/ 0.78	35.6/ 0.90	33.5/ 0.87	37.2/ 0.96	38.6/ 0.96
18	flowers_plants_23	30.9/ 0.81	32.9/ 0.86	30.8/ 0.76	35.0/ 0.90	33.3/ 0.85	37.3/ 0.94	37.8/ 0.95
19	flowers_plants_24	27.5/ 0.74	32.0/ 0.83	28.5/ 0.75	33.6/ 0.88	32.3/ 0.84	34.3/ 0.92	35.1/ 0.93
20	flowers_plants_25	26.6/ 0.73	31.1/ 0.83	28.7/ 0.79	32.9/ 0.87	31.5/ 0.85	33.6/ 0.92	34.1/ 0.92
21	fruits_vegetables_2	28.1/ 0.81	31.5/ 0.87	28.8/ 0.79	34.1/ 0.91	32.5/ 0.88	35.1/ 0.94	35.8/ 0.95
22	fruits_vegetables_3	22.5/ 0.87	29.3/ 0.89	24.9/ 0.82	30.4/ 0.91	31.6/ 0.92	28.8/ 0.94	29.4/ 0.95
23	fruits_vegetables_4	27.1/ 0.86	32.5/ 0.86	28.4/ 0.79	34.2/ 0.90	33.1/ 0.87	33.2/ 0.95	34.6/ 0.95
24	fruits_vegetables_5	25.3/ 0.77	32.4/ 0.86	27.0/ 0.76	33.8/ 0.90	32.8/ 0.87	31.1/ 0.92	32.3/ 0.93
25	fruits_vegetables_6	26.0/ 0.81	32.1/ 0.86	27.5/ 0.77	33.6/ 0.90	32.7/ 0.87	31.5/ 0.93	32.5/ 0.94
26	people_5	28.6/ 0.86	32.5/ 0.87	28.5/ 0.78	35.0/ 0.91	33.0/ 0.86	34.2/ 0.94	36.4/ 0.95
27	people_6	33.8/ 0.89	33.7/ 0.88	32.9/ 0.82	35.7/ 0.91	33.3/ 0.84	37.6/ 0.94	38.4/ 0.95
28	people_7	36.7/ 0.90	40.8/ 0.95	33.9/ 0.76	42.4/ 0.97	36.6/ 0.85	41.4/ 0.97	43.7/ 0.97
29	people_8	36.0/ 0.90	35.0/ 0.87	33.7/ 0.80	36.4/ 0.89	33.8/ 0.81	39.4/ 0.95	40.1/ 0.95
30	people_9	32.8/ 0.86	33.6/ 0.84	32.7/ 0.80	35.0/ 0.87	32.6/ 0.77	37.8/ 0.93	38.2/ 0.93
Average		29.9/ 0.85	33.0/ 0.87	30.2/ 0.79	34.9/ 0.90	33.2/ 0.85	35.5/ 0.94	36.6/ 0.95

TABLE III: LF Denoising results for the testing dataset at noise level $\sigma = 50$. Each result entry is in the format of PSNR (dB)/ SSIM.

Methods / Data		Avg-All	BM3D	HyperFan4D	V-BM4D	LFBM5D	APA-syn	APA
1	bikes_2	27.2/ 0.71	26.5/ 0.73	27.7/ 0.73	28.8/ 0.79	26.5/ 0.71	31.7/ 0.90	32.0/ 0.91
2	bikes_3	24.3/ 0.61	26.4/ 0.72	24.7/ 0.64	28.5/ 0.78	26.3/ 0.70	31.3/ 0.89	31.3/ 0.89
3	bikes_4	25.1/ 0.70	25.4/ 0.70	25.6/ 0.73	27.8/ 0.77	26.6/ 0.76	31.1/ 0.91	31.0/ 0.91
4	bikes_5	25.1/ 0.70	26.6/ 0.69	25.4/ 0.72	28.5/ 0.75	27.8/ 0.76	31.0/ 0.90	31.2/ 0.90
5	bikes_6	23.7/ 0.69	27.5/ 0.75	24.0/ 0.71	28.9/ 0.80	27.7/ 0.79	29.6/ 0.89	30.0/ 0.90
6	buildings_21	30.2/ 0.65	31.2/ 0.82	30.5/ 0.66	33.0/ 0.86	29.9/ 0.73	37.3/ 0.93	37.6/ 0.93
7	buildings_22	31.3/ 0.66	32.6/ 0.87	31.3/ 0.66	33.8/ 0.89	29.6/ 0.72	37.4/ 0.95	38.2/ 0.95
8	buildings_23	27.0/ 0.53	30.7/ 0.77	27.4/ 0.55	32.0/ 0.79	29.8/ 0.70	33.1/ 0.85	34.1/ 0.86
9	buildings_24	25.9/ 0.57	30.4/ 0.80	26.2/ 0.58	31.9/ 0.83	27.9/ 0.64	33.2/ 0.89	33.8/ 0.90
10	buildings_25	28.7/ 0.57	36.0/ 0.85	29.4/ 0.61	36.8/ 0.85	30.5/ 0.75	35.9/ 0.90	37.4/ 0.91
11	cars_21	27.6/ 0.68	27.7/ 0.75	28.1/ 0.71	29.8/ 0.79	28.5/ 0.76	33.1/ 0.90	33.3/ 0.90
12	cars_22	31.5/ 0.69	30.5/ 0.82	32.1/ 0.72	33.1/ 0.84	29.6/ 0.73	36.8/ 0.93	37.1/ 0.93
13	cars_23	31.8/ 0.62	32.6/ 0.80	33.2/ 0.67	34.7/ 0.80	34.3/ 0.83	39.6/ 0.93	39.9/ 0.93
14	cars_24	30.3/ 0.83	25.7/ 0.53	30.4/ 0.83	27.0/ 0.58	25.6/ 0.60	32.3/ 0.88	32.4/ 0.88
15	cars_25	30.8/ 0.83	26.3/ 0.60	30.8/ 0.83	27.7/ 0.65	25.7/ 0.62	32.9/ 0.89	33.0/ 0.90
16	flowers_plants_21	24.2/ 0.74	24.3/ 0.74	24.5/ 0.75	26.6/ 0.82	25.4/ 0.81	30.8/ 0.93	31.0/ 0.93
17	flowers_plants_22	28.6/ 0.66	29.8/ 0.79	28.8/ 0.66	31.5/ 0.82	28.7/ 0.79	35.0/ 0.92	35.4/ 0.92
18	flowers_plants_23	28.8/ 0.65	28.6/ 0.71	28.9/ 0.65	30.4/ 0.77	29.6/ 0.76	34.8/ 0.90	35.0/ 0.91
19	flowers_plants_24	26.4/ 0.61	27.8/ 0.69	26.6/ 0.62	29.3/ 0.74	27.8/ 0.70	32.3/ 0.87	32.5/ 0.87
20	flowers_plants_25	25.7/ 0.62	26.9/ 0.67	25.9/ 0.63	28.5/ 0.72	26.4/ 0.68	31.4/ 0.86	31.6/ 0.86
21	fruits_vegetables_2	26.8/ 0.67	26.9/ 0.73	27.0/ 0.68	29.1/ 0.79	27.5/ 0.78	32.8/ 0.91	33.1/ 0.91
22	fruits_vegetables_3	22.0/ 0.73	23.0/ 0.78	22.5/ 0.74	25.7/ 0.83	27.2/ 0.86	26.9/ 0.91	27.1/ 0.91
23	fruits_vegetables_4	26.1/ 0.68	28.1/ 0.75	26.3/ 0.69	29.9/ 0.80	29.0/ 0.79	31.8/ 0.91	32.1/ 0.92
24	fruits_vegetables_5	24.6/ 0.60	28.0/ 0.74	24.8/ 0.61	29.5/ 0.79	28.7/ 0.78	29.9/ 0.88	30.1/ 0.88
25	fruits_vegetables_6	25.2/ 0.65	27.8/ 0.73	25.4/ 0.66	29.3/ 0.78	28.6/ 0.78	30.3/ 0.89	30.4/ 0.89
26	people_5	27.1/ 0.68	28.6/ 0.77	27.4/ 0.70	30.4/ 0.82	26.5/ 0.71	32.7/ 0.91	33.3/ 0.91
27	people_6	30.3/ 0.71	29.2/ 0.78	30.5/ 0.72	31.3/ 0.82	28.7/ 0.76	35.5/ 0.91	35.9/ 0.92
28	people_7	31.3/ 0.62	35.9/ 0.91	31.7/ 0.64	37.7/ 0.92	28.4/ 0.70	39.7/ 0.96	40.5/ 0.96
29	people_8	31.1/ 0.68	31.7/ 0.79	31.4/ 0.70	33.2/ 0.82	29.2/ 0.68	36.9/ 0.91	37.1/ 0.91
30	people_9	29.8/ 0.67	29.9/ 0.76	30.0/ 0.68	31.6/ 0.79	25.0/ 0.49	35.4/ 0.89	35.6/ 0.89
Average		27.6/ 0.67	28.7/ 0.75	27.9/ 0.68	30.5/ 0.79	28.1/ 0.73	33.4/ 0.90	33.8/ 0.91

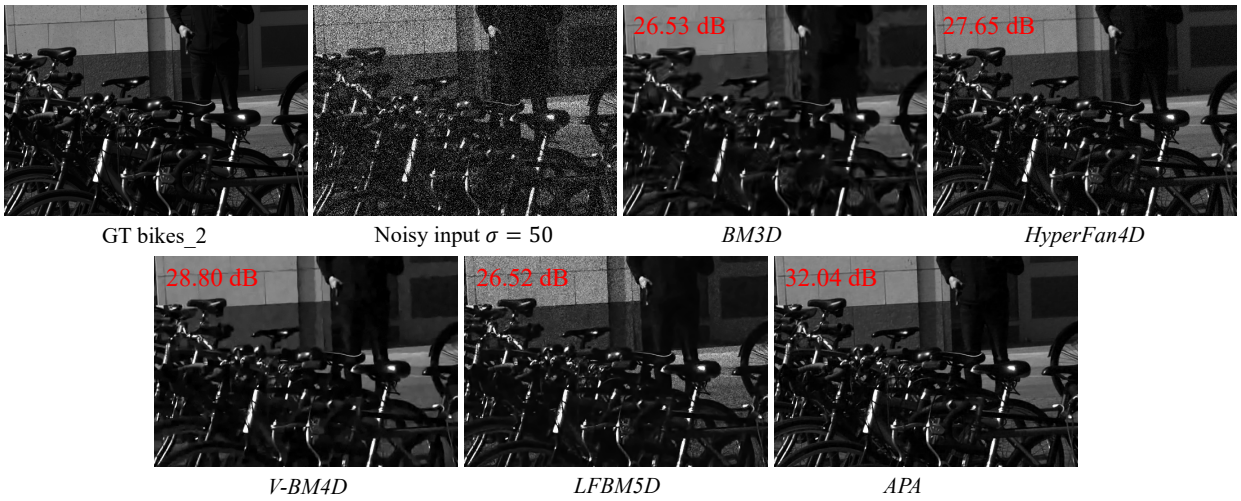

Fig. 3: Visual comparison between different denoisers for the testing LF data “bikes_2” at noise level $\sigma = 50$.

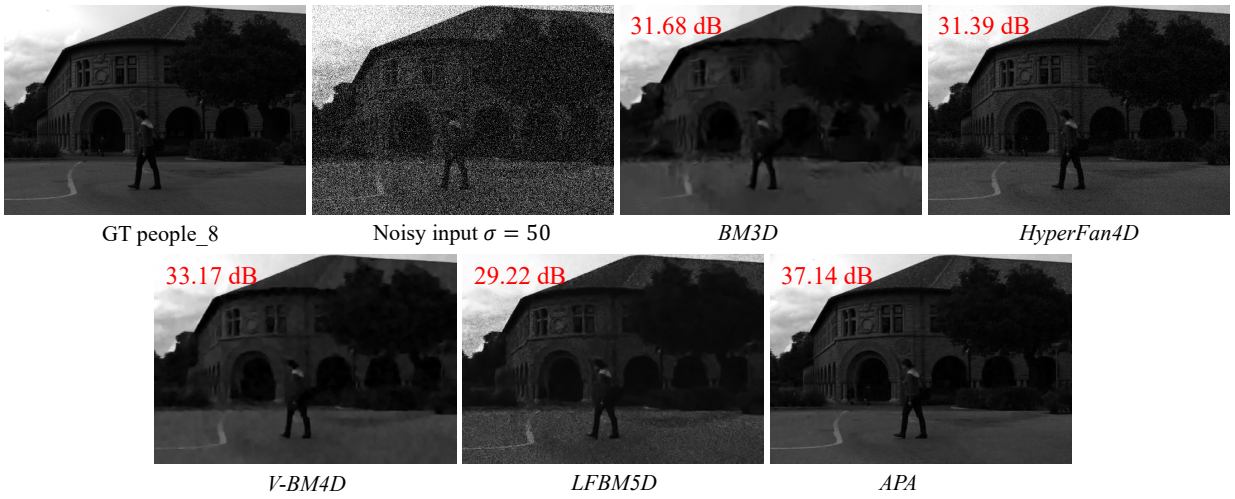

Fig. 4: Visual comparison between different denoisers for the testing LF data ‘people_8” at noise level $\sigma = 50$.

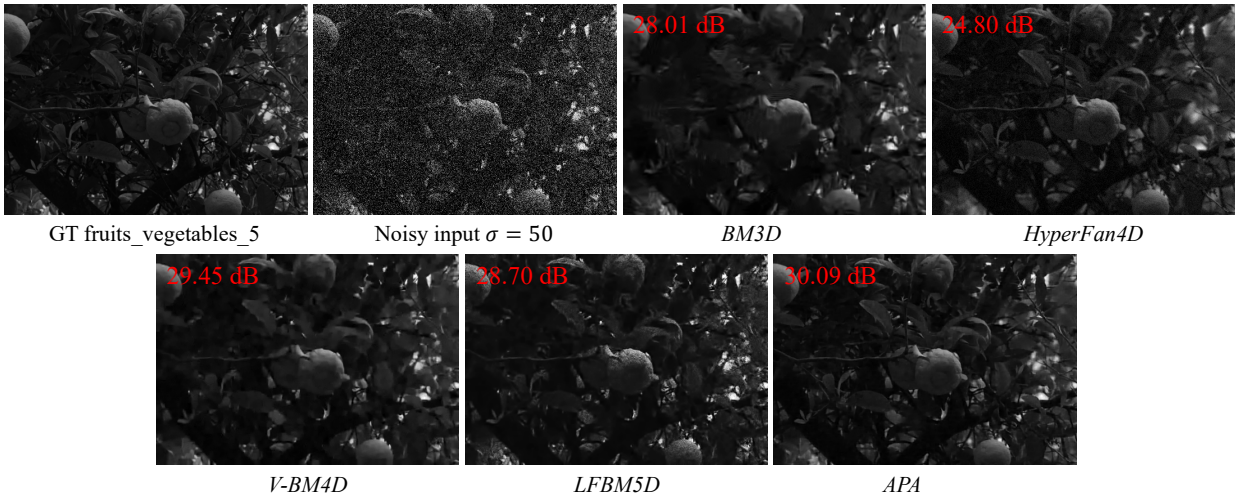

Fig. 5: Visual comparison between different denoisers for the testing LF data "fruits_vegetables_5" at noise level $\sigma = 50$.

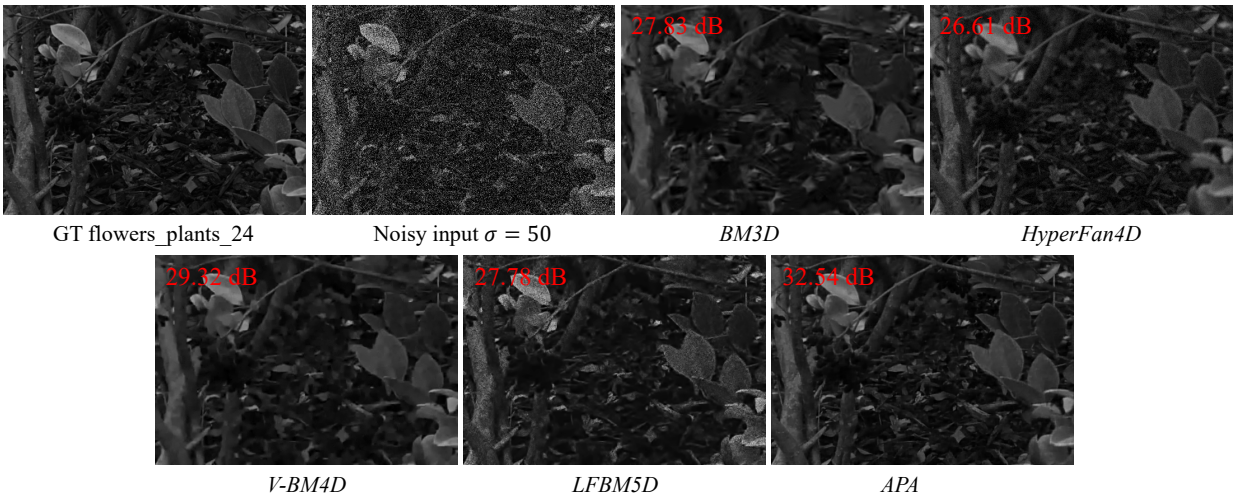

Fig. 6: Visual comparison between different denoisers for the testing LF data "flowers_plants_24" at noise level $\sigma = 50$.

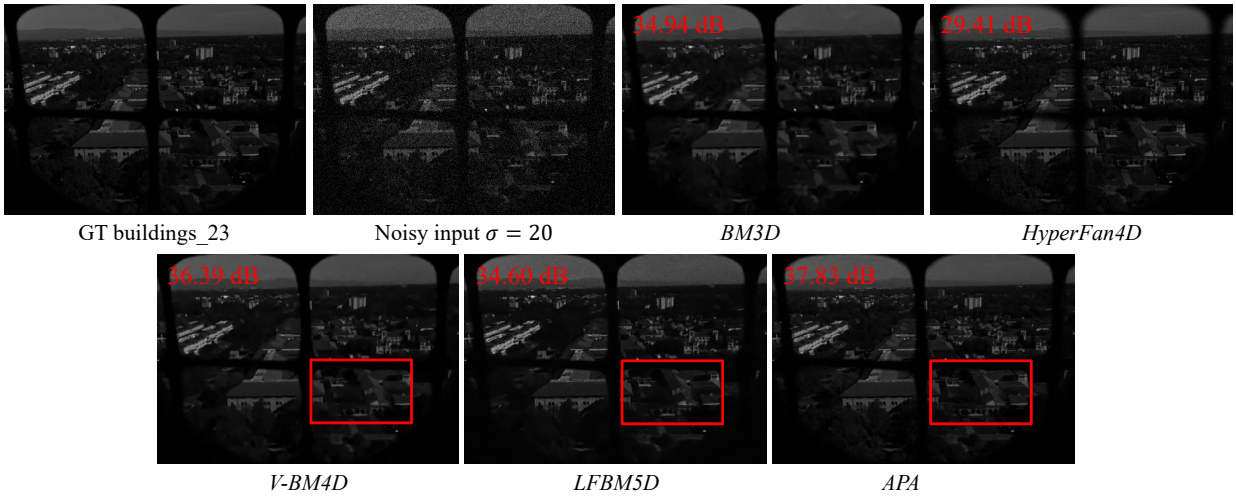

Fig. 7: Visual comparison between different denoisers for the testing LF data 'buildings_23" at noise level $\sigma = 20$.

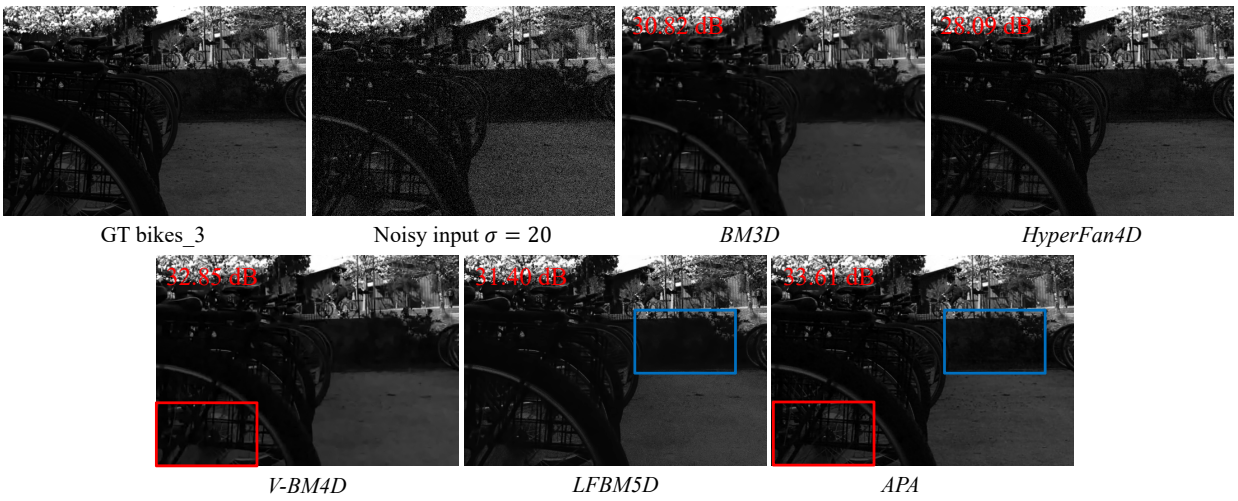

Fig. 8: Visual comparison between different denoisers for the testing LF data "bikes_3" at noise level $\sigma = 20$.

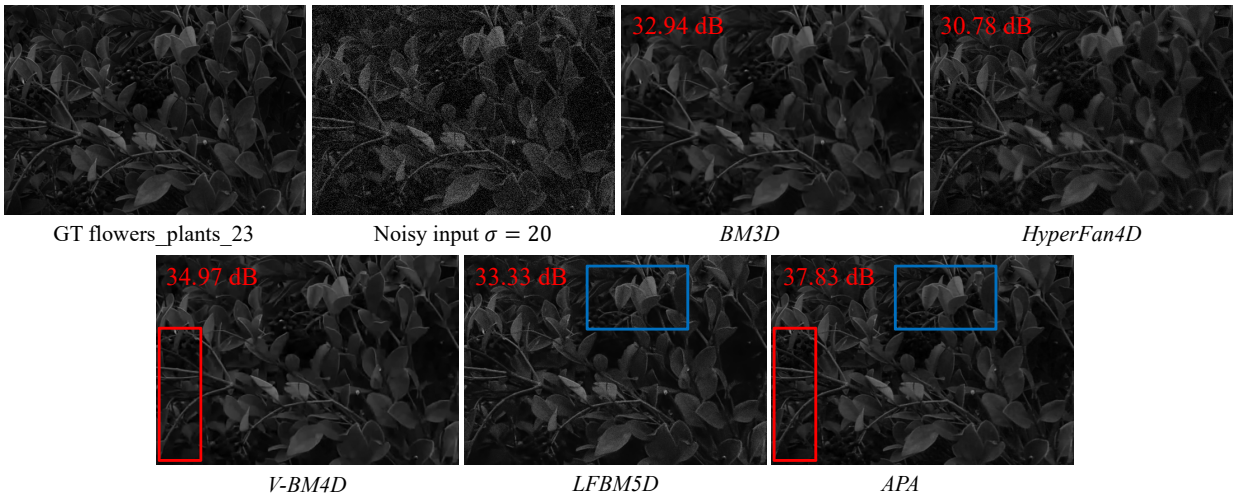

Fig. 9: Visual comparison between different denoisers for the testing LF data "flowers_plants_23" at noise level $\sigma = 20$.

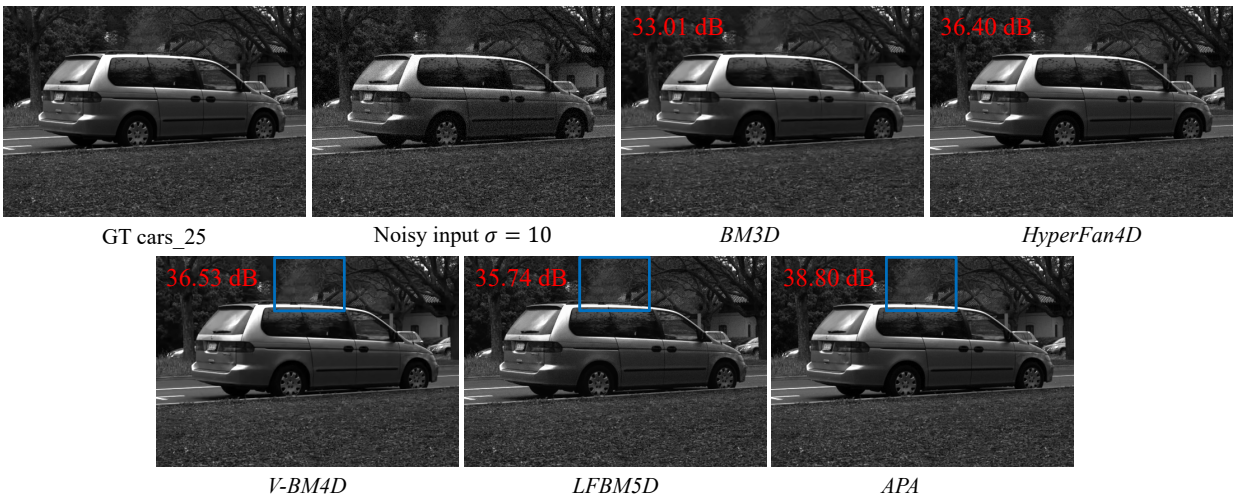

Fig. 10: Visual comparison between different denoisers for the testing LF data "cars_25" at noise level $\sigma = 10$.

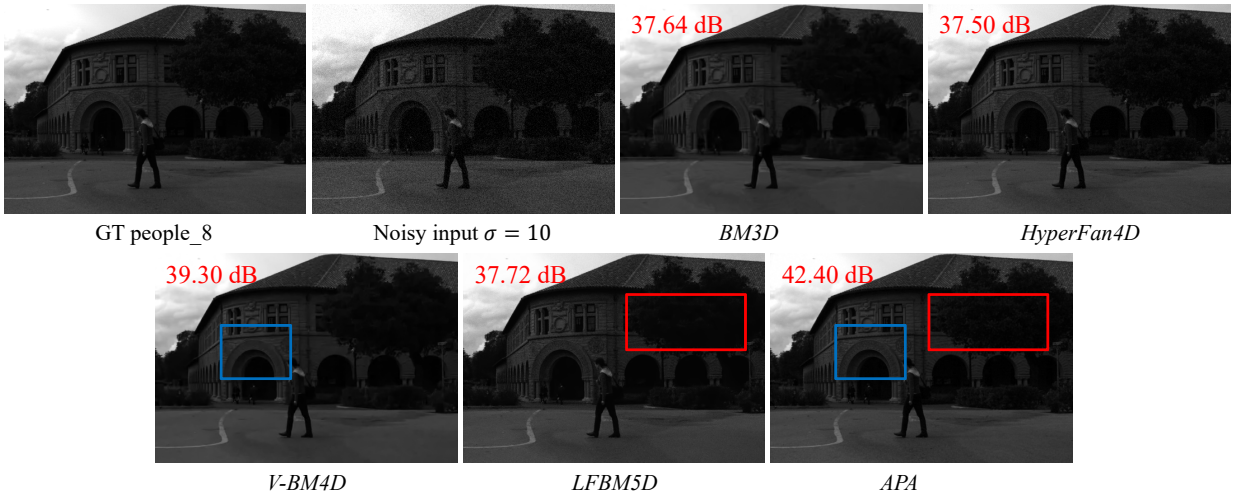

Fig. 11: Visual comparison between different denoisers for the testing LF data "people_8" at noise level $\sigma = 10$.