Supplementary Material:
An algorithm for improving Non-Local Means operators via low-rank approximation

Contents

General

This supplementary complements the experiments reported in Section 5 of the paper. First, we present the set of test images used in Subsections 5.1–5.2. Then, we depict the results of denoising with NLM, NLM-SB, Iterated-NLM, and BM3D for all test images. This part is divided into three subsections, corresponding to the three noise levels used. Each subsection presents for each test image the clean image, its noisy version, and the denoised images. We conclude the comparisons with a table of PSNR values of the above experiments.
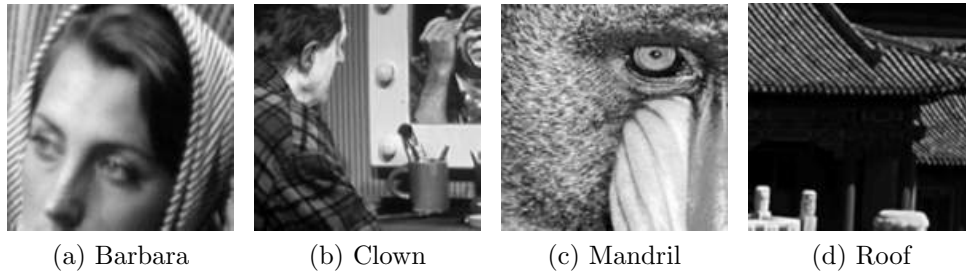
1 Test images for Subsections 5.1–5.2

(a) Barbara   (b) Clown   (c) Mandril   (d) Roof

Figure 1: Four test images for Subsections 5.1–5.2

(a) Boat   (b) Couple   (c) Couple 2   (d) Hill

(e) House   (f) Lake   (g) Lena   (h) Man
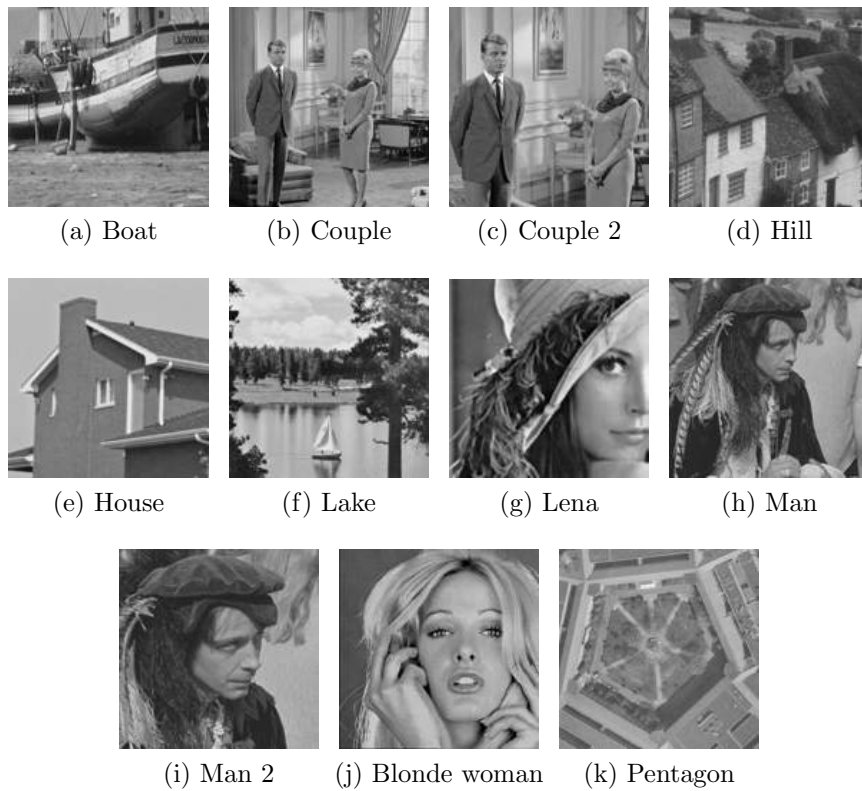
(i) Man 2   (j) Blonde woman   (k) Pentagon

Figure 2: Additional test images for Subsection 5.2

2 Comparisons with SNR=0.50

(a) Clean

(b) NLM
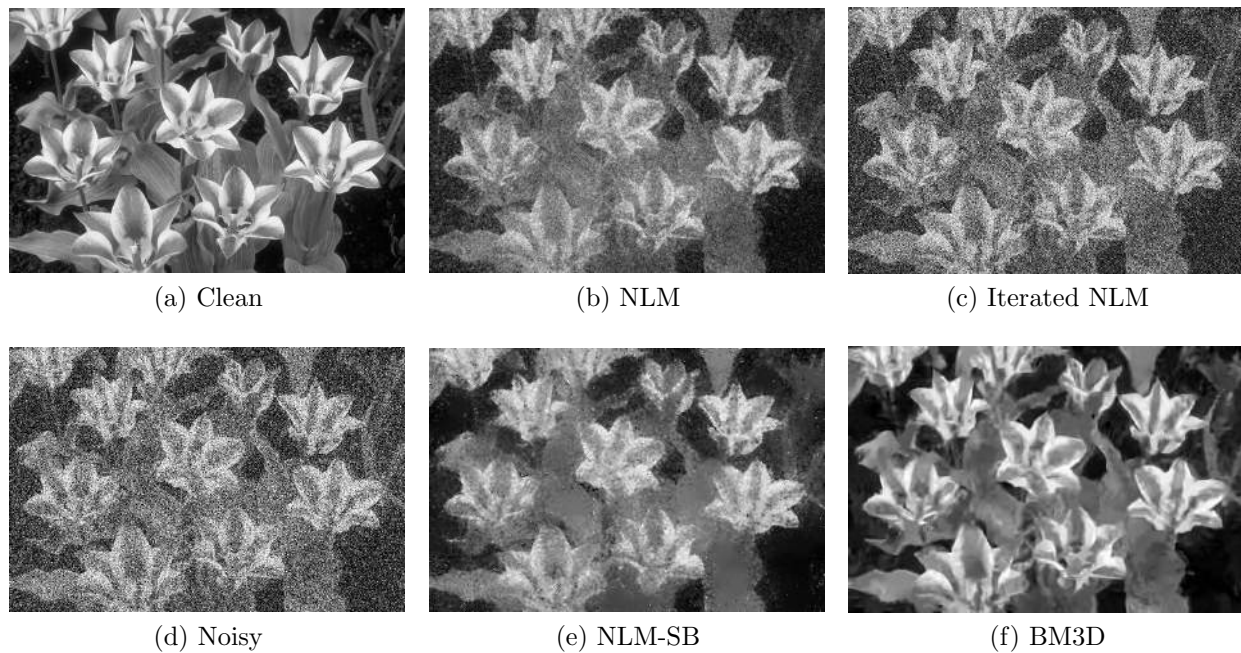
(c) Iterated NLM

(d) Noisy
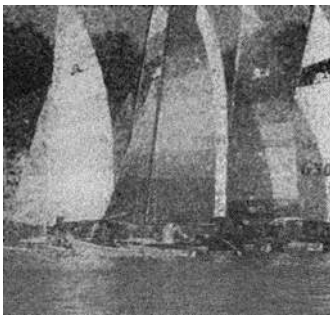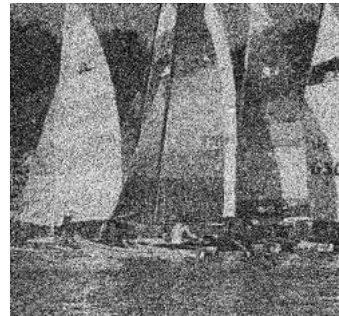
(e) NLM-SB

(f) BM3D

Figure 3: *tulips*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM
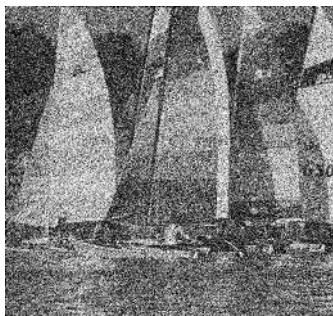
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 4: *yacht*, SNR=0.5
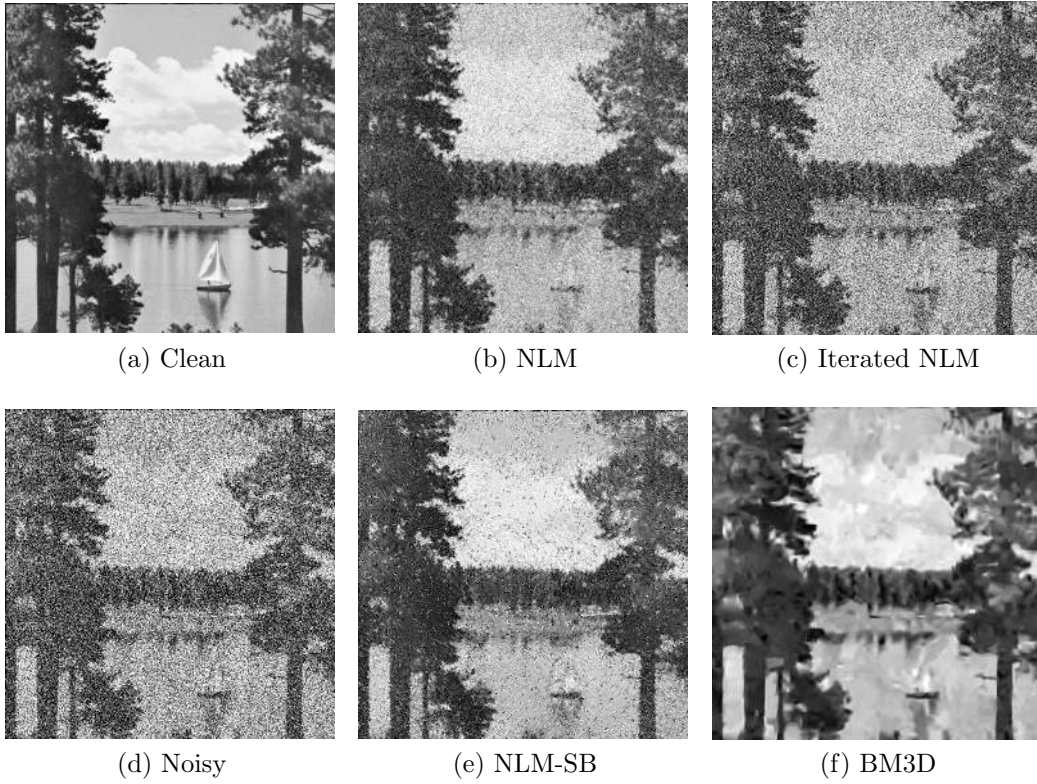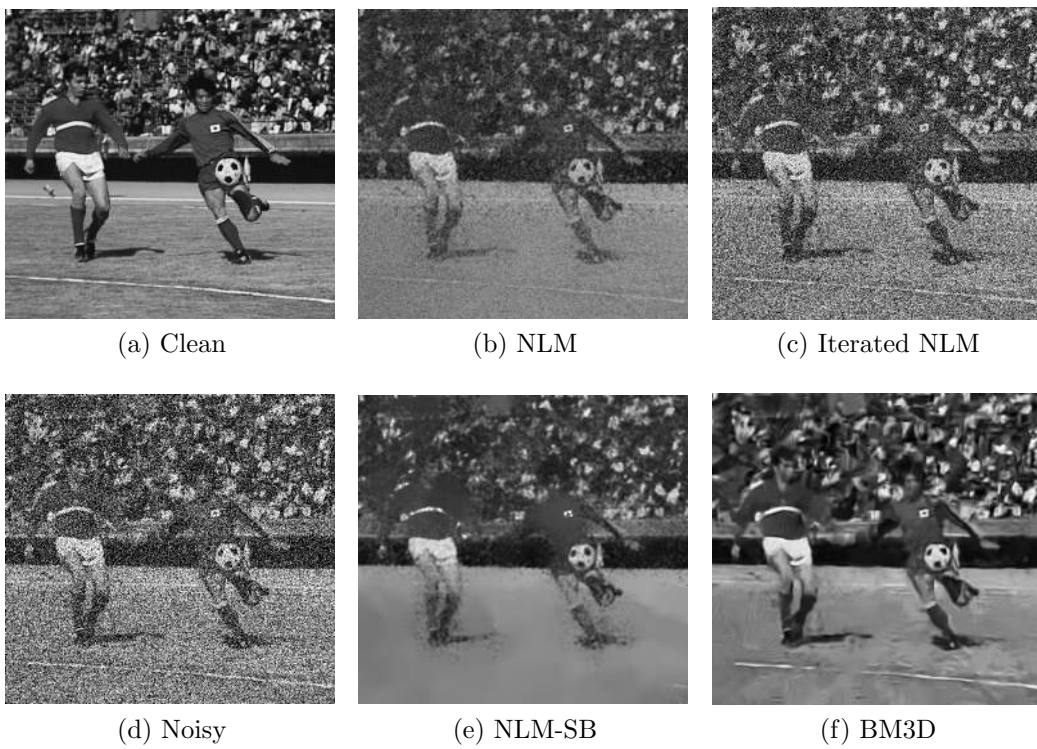
(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 5: *sailboat*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 6: *soccer*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 7: *pens*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 8: *peppers*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
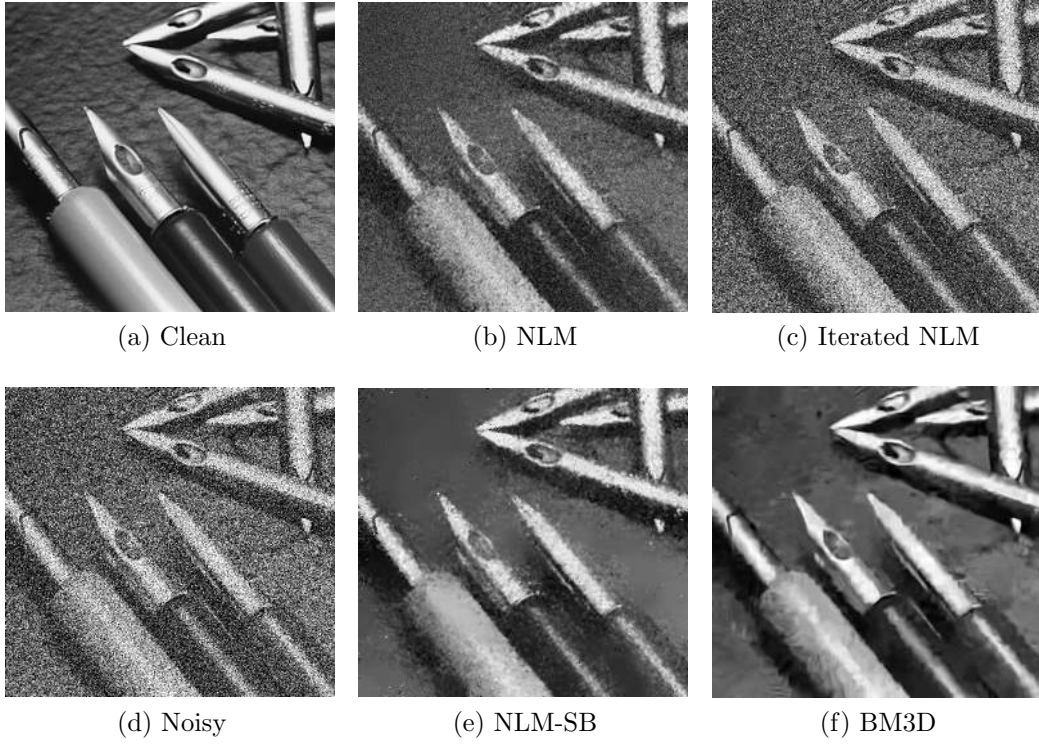
Figure 9: *monarch*, SNR=0.5
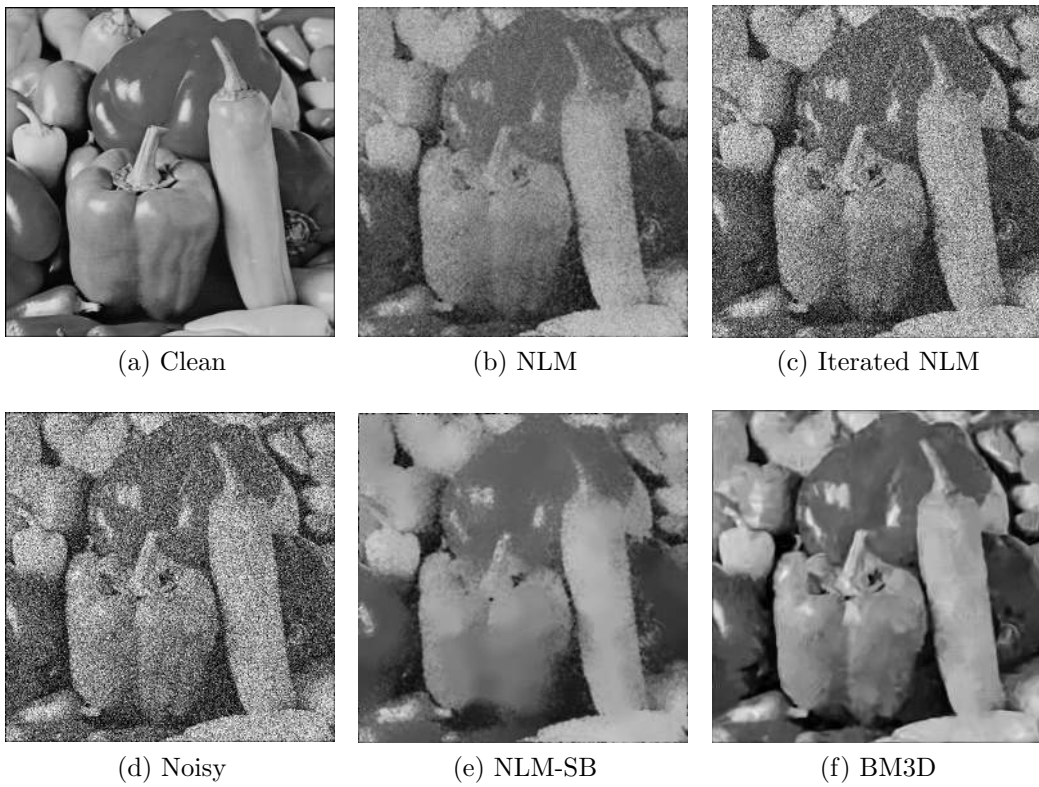
(a) Clean   (b) NLM   (c) Iterated NLM
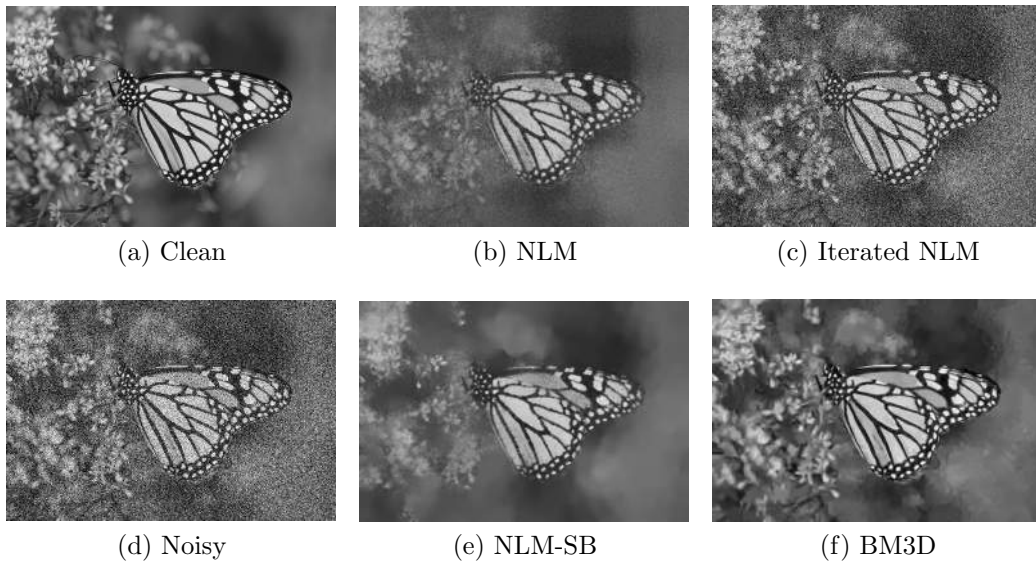
(d) Noisy   (e) NLM-SB   (f) BM3D
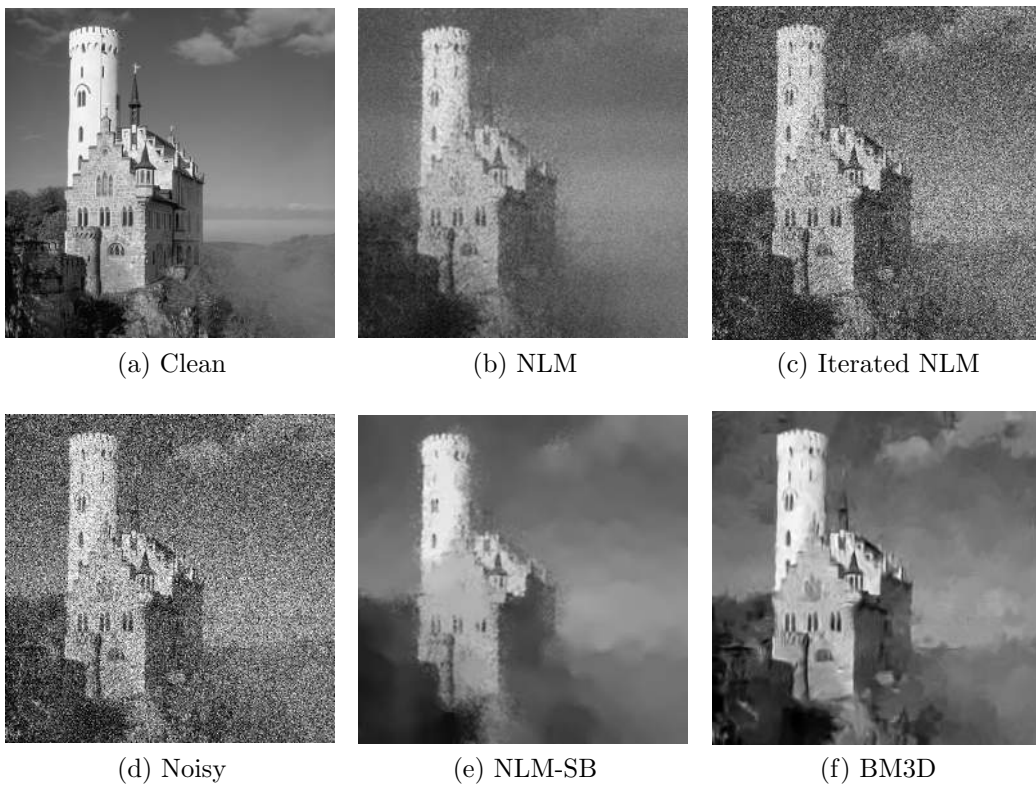
Figure 10: *Lichtenstein*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 11: *lighthouse*, SNR=0.5

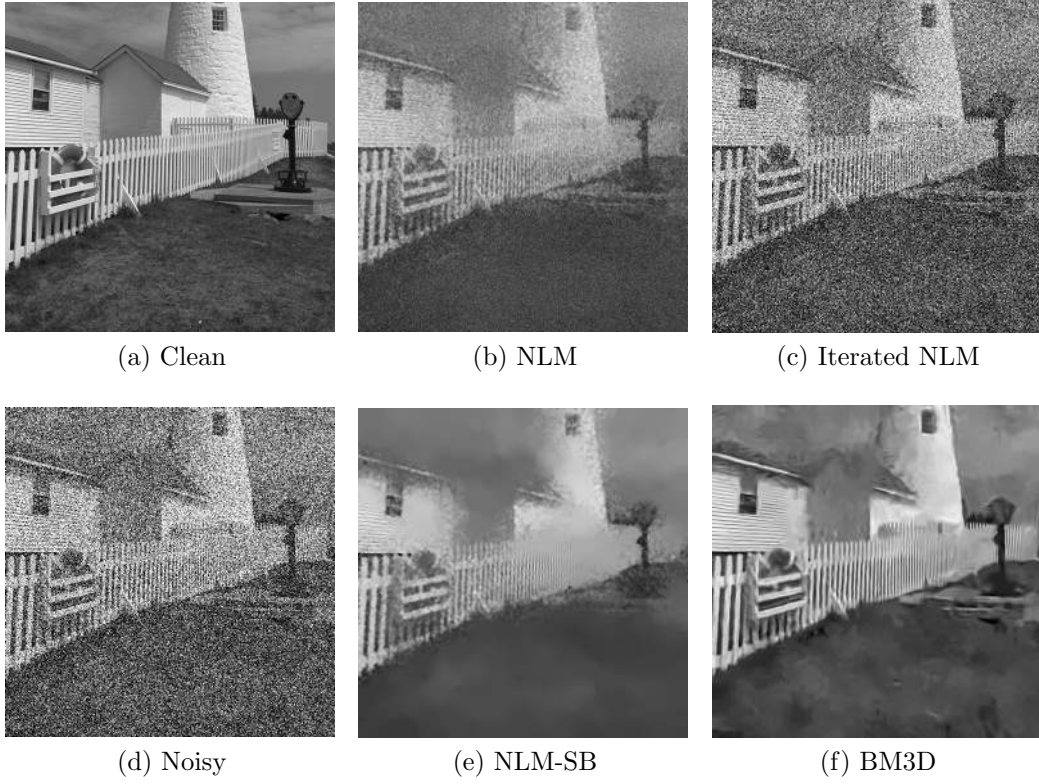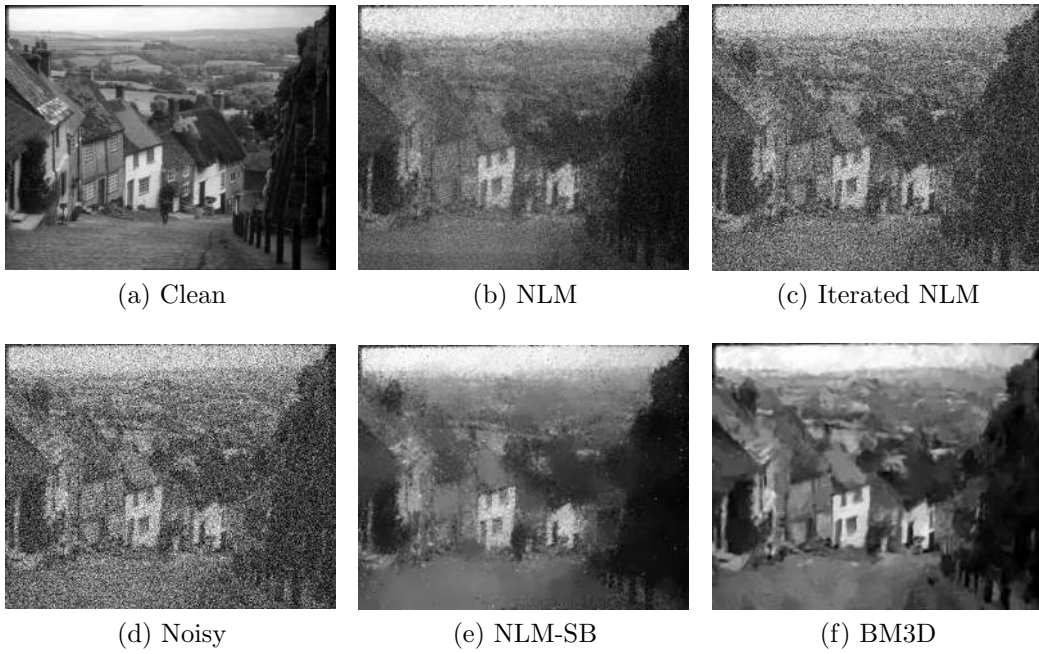(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 12: *goldhill*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM
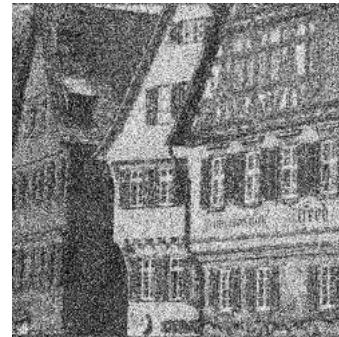
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 13: *houses*, SNR=0.5
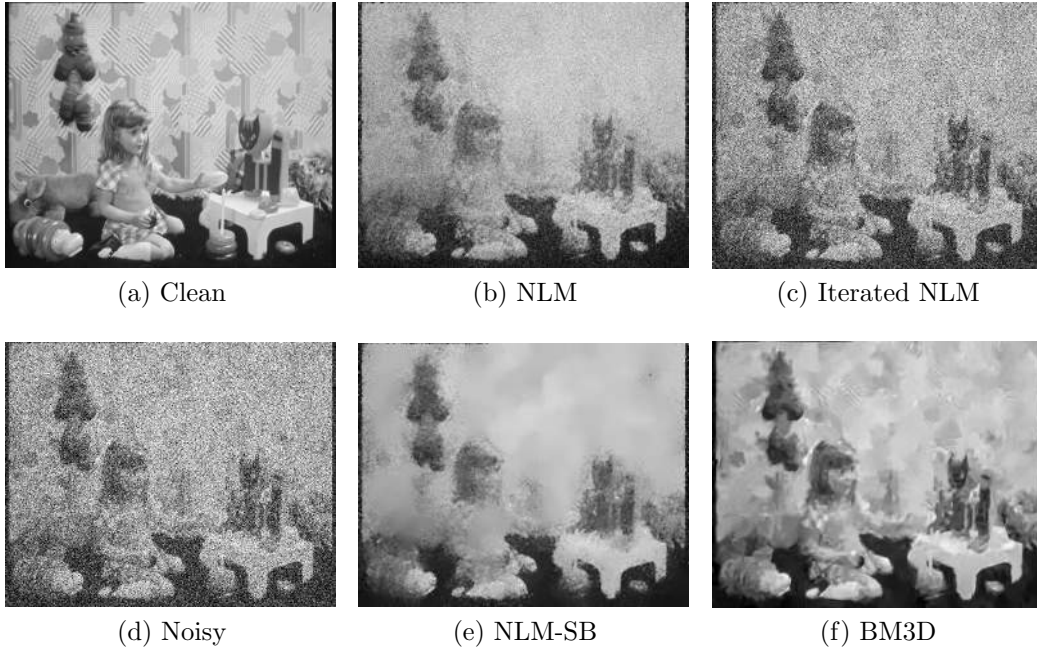
(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 14: *girlface*, SNR=0.5

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D

Figure 15: *girl*, SNR=0.5

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D

Figure 16: *crowd*, SNR=0.5

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(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 17: *flower*, SNR=0.5
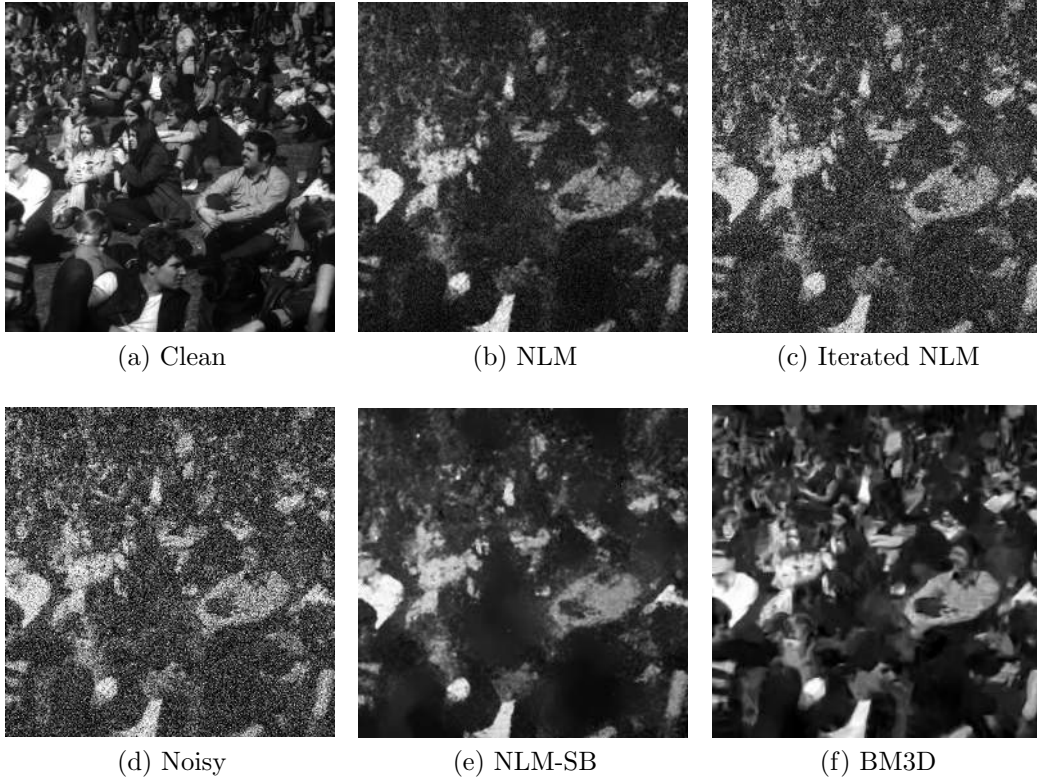
(a) Clean   (b) NLM   (c) Iterated NLM
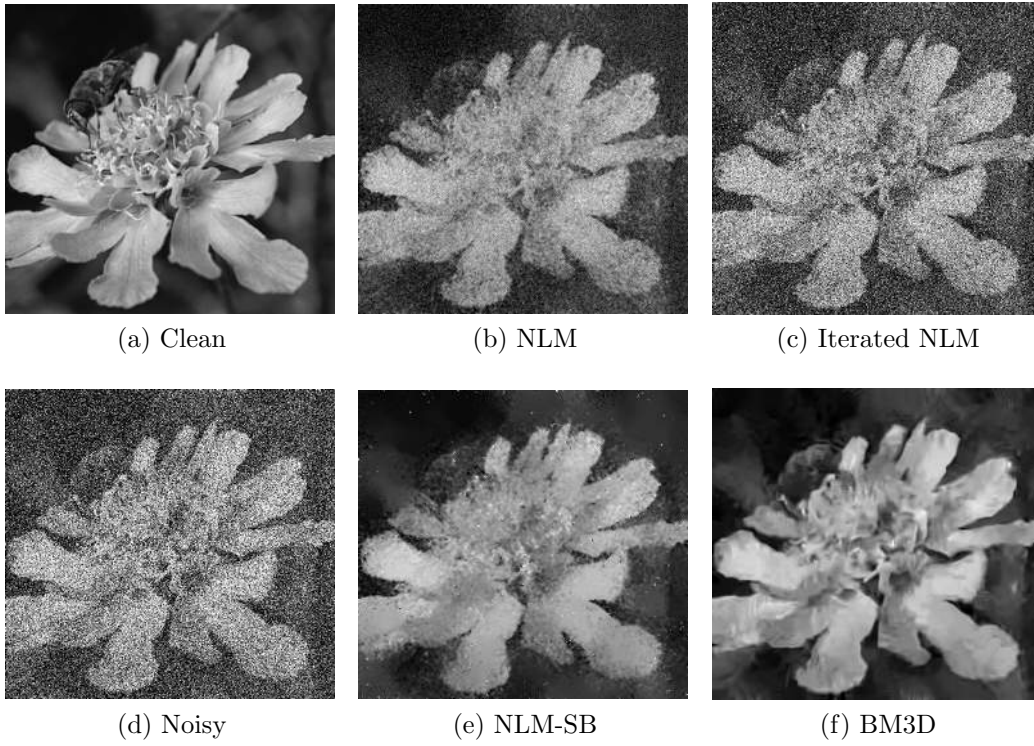
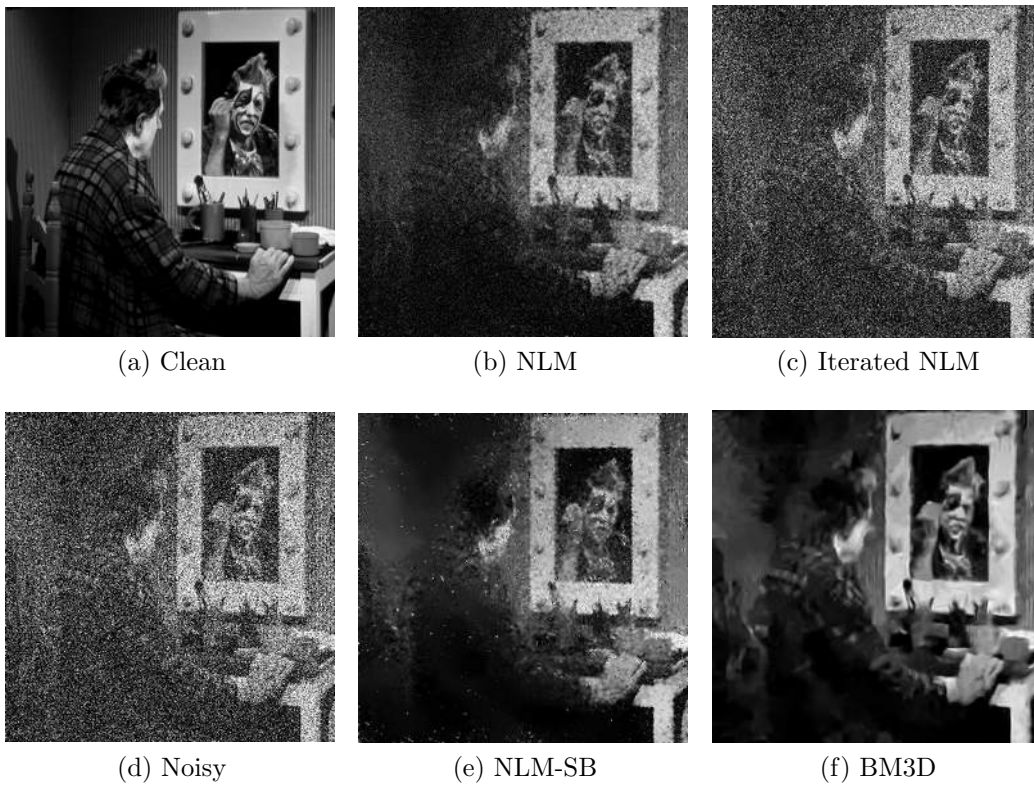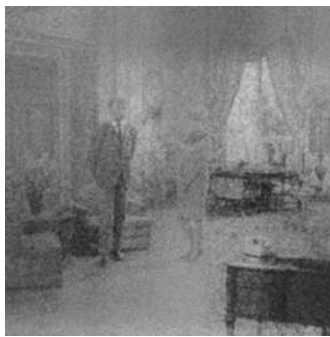(d) Noisy   (e) NLM-SB   (f) BM3D
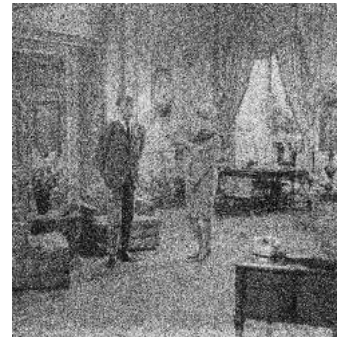
Figure 18: *clown*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM
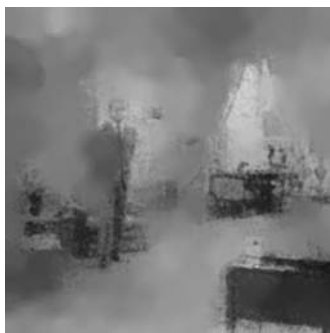
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 19: *couple*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 20: *cameraman*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
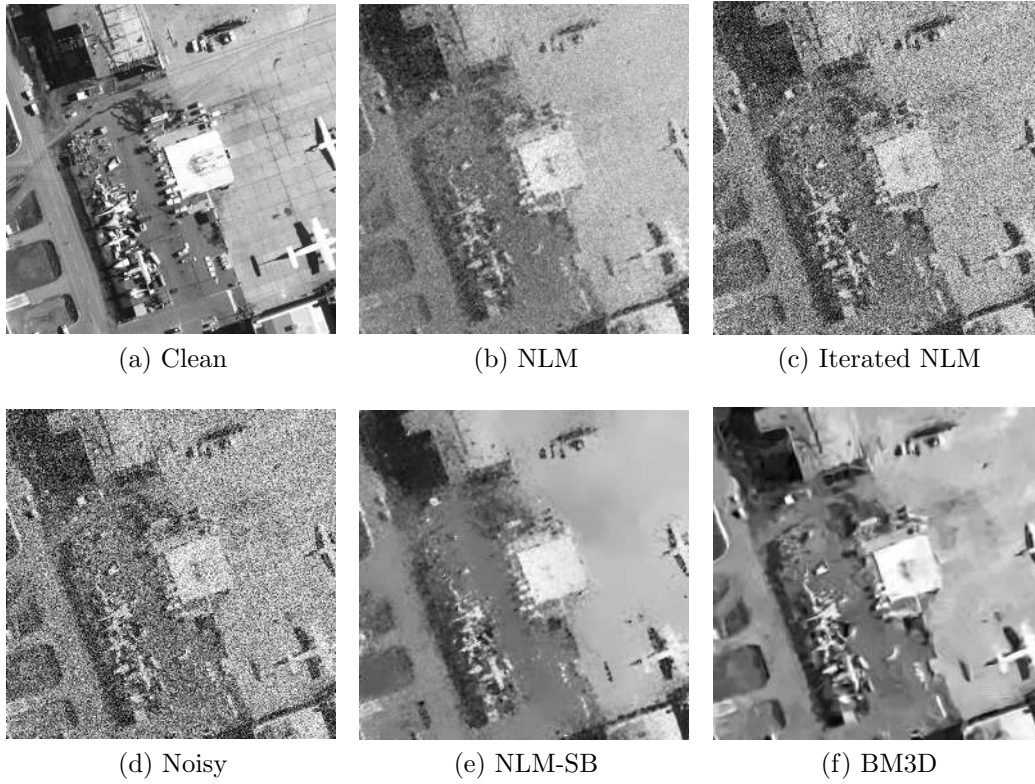
Figure 21: *airfield*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 22: *boats*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 23: *cat*, SNR=0.5

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
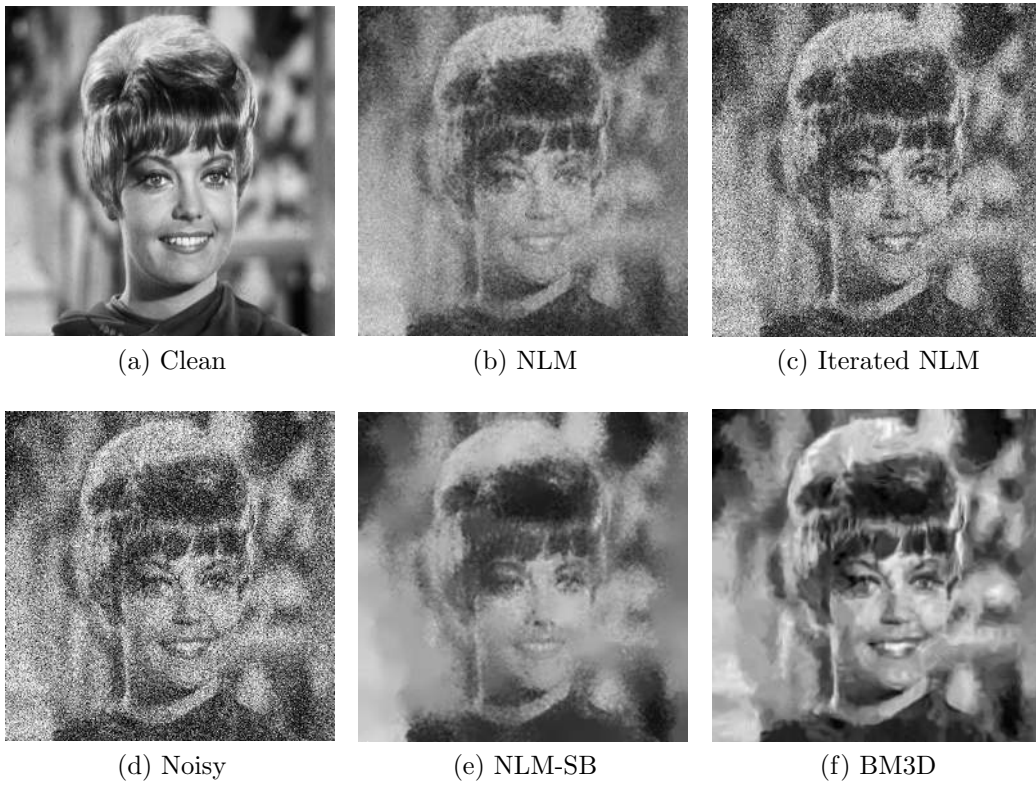
Figure 24: *zelda*, SNR=0.5

3   Comparisons with SNR=0.75
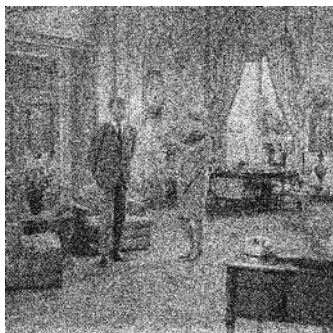

(a) Clean   (b) NLM   (c) Iterated NLM
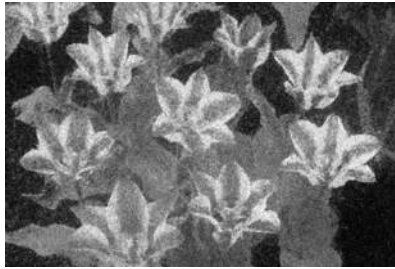
(d) Noisy   (e) NLM-SB   (f) BM3D
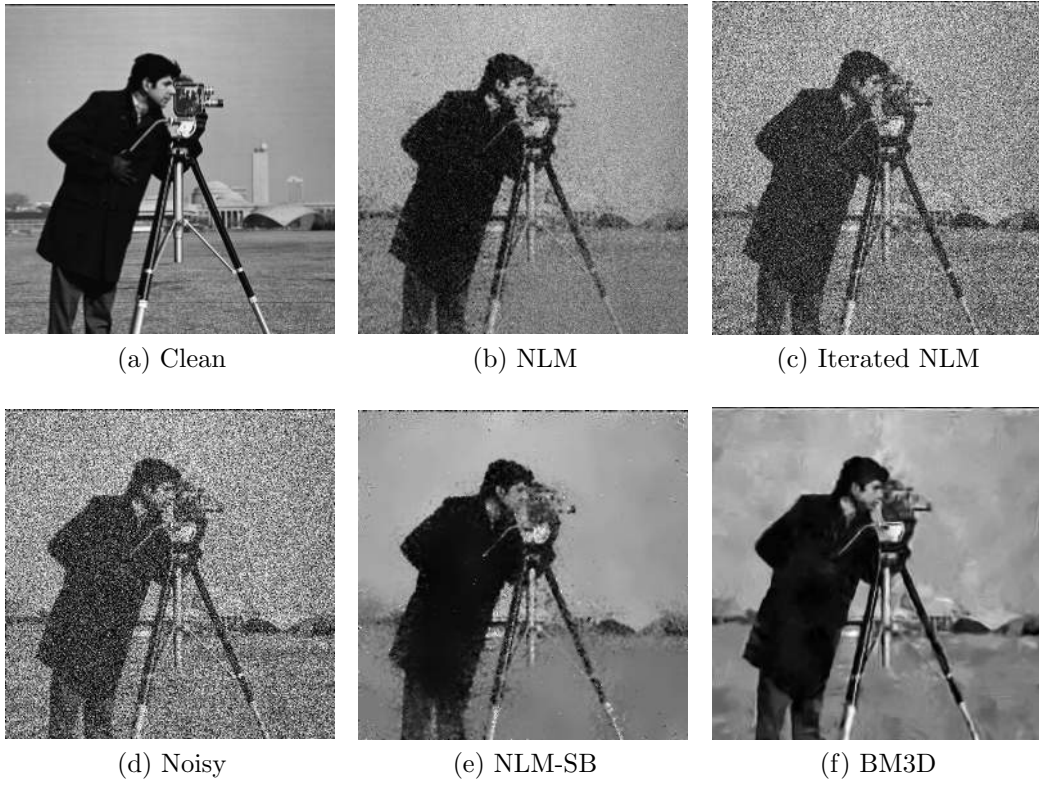
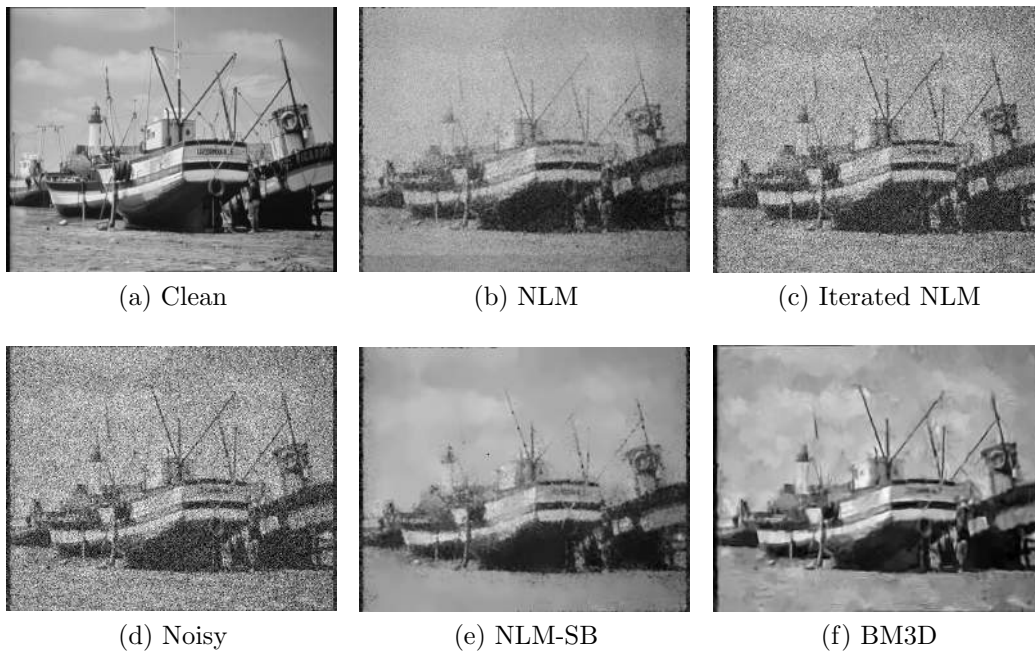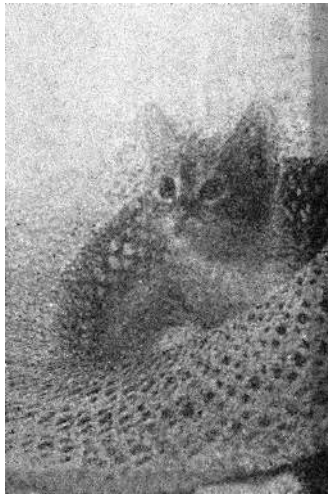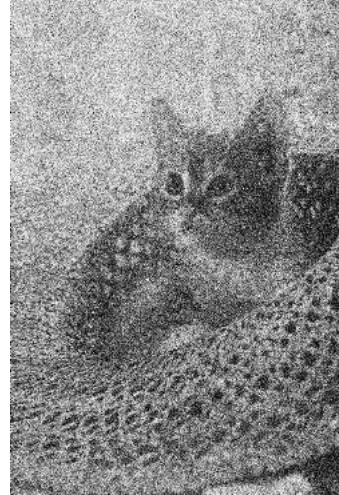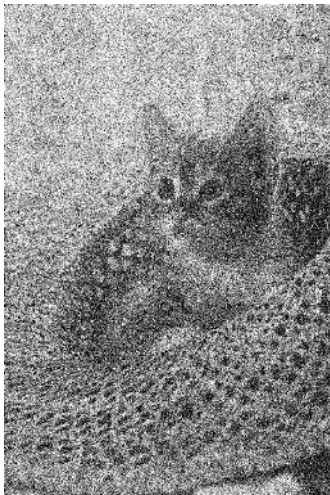Figure 25: *tulips*, SNR=0.75

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D

Figure 26: *yacht*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 27: *sailboat*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 28: *soccer*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 29: *pens*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
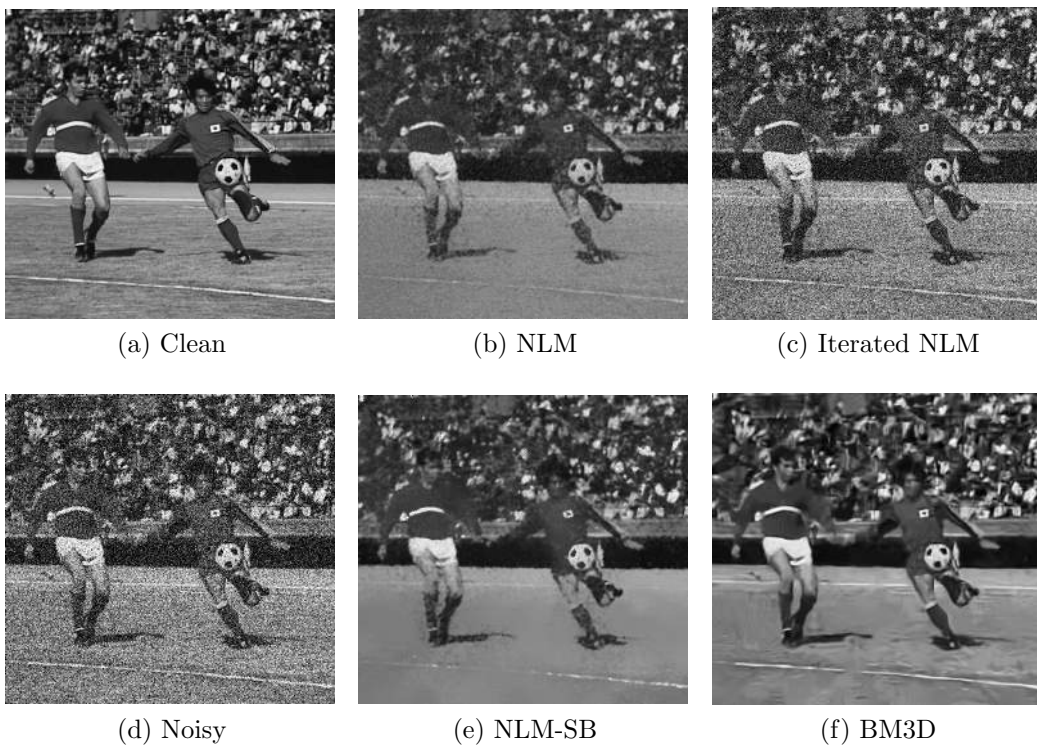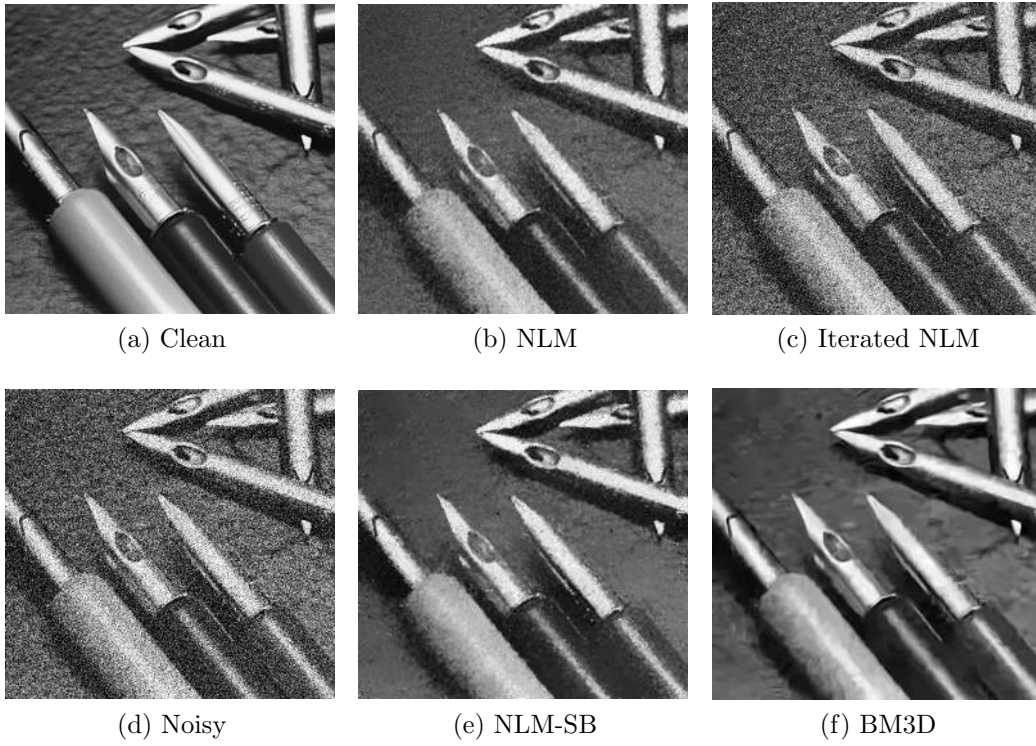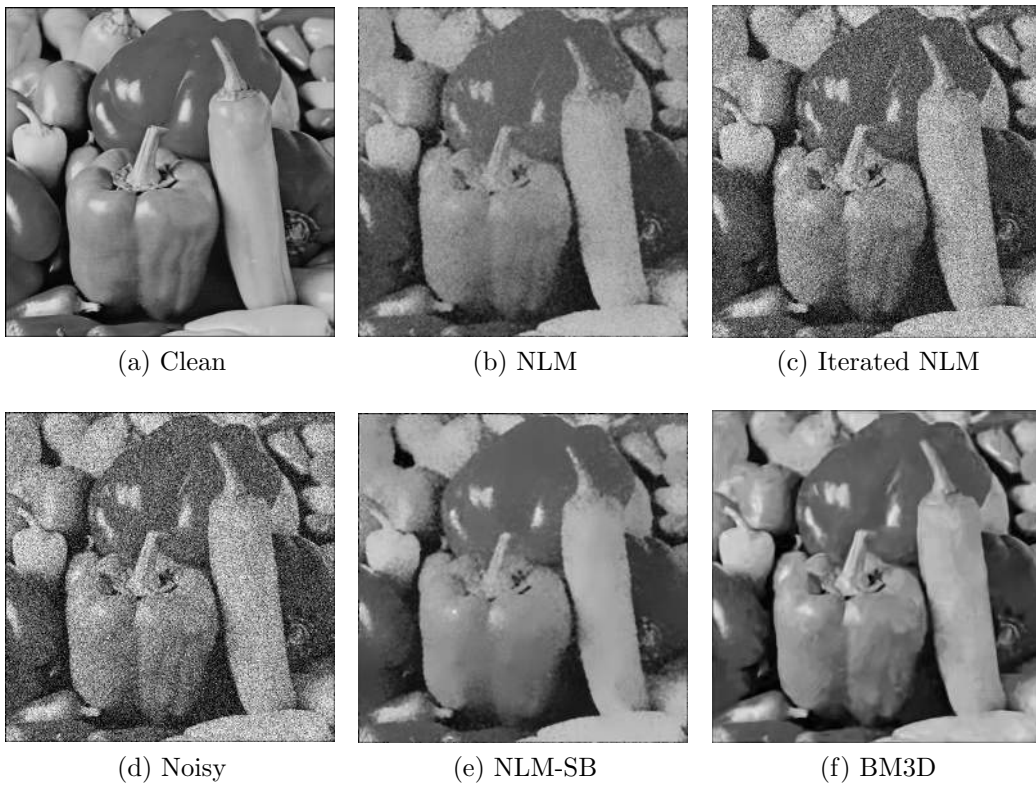
Figure 30: *peppers*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
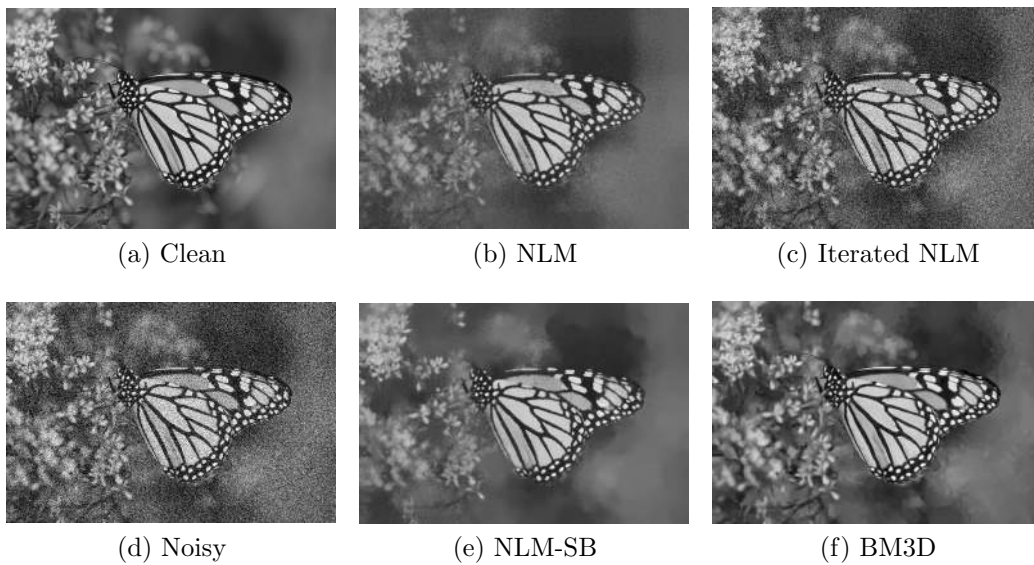
Figure 31: *monarch*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

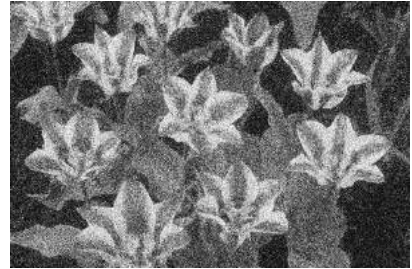(d) Noisy   (e) NLM-SB   (f) BM3D
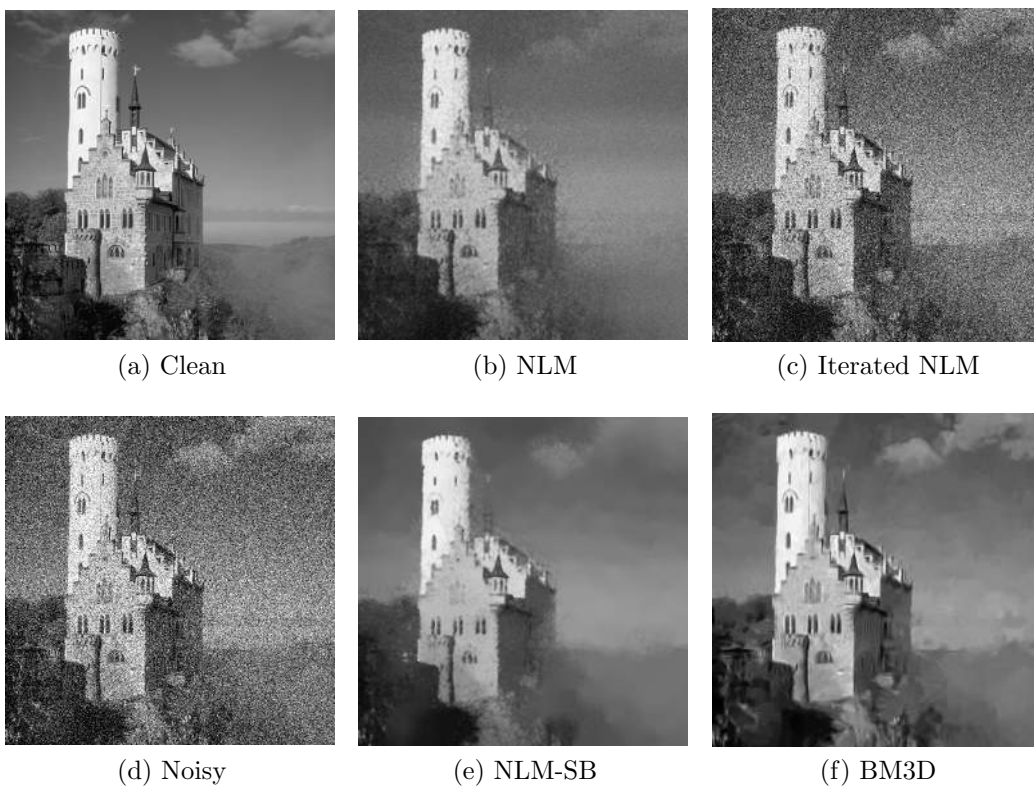
Figure 32: *Lichtenstein*, SNR=0.75
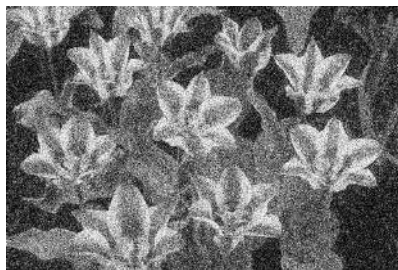
(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
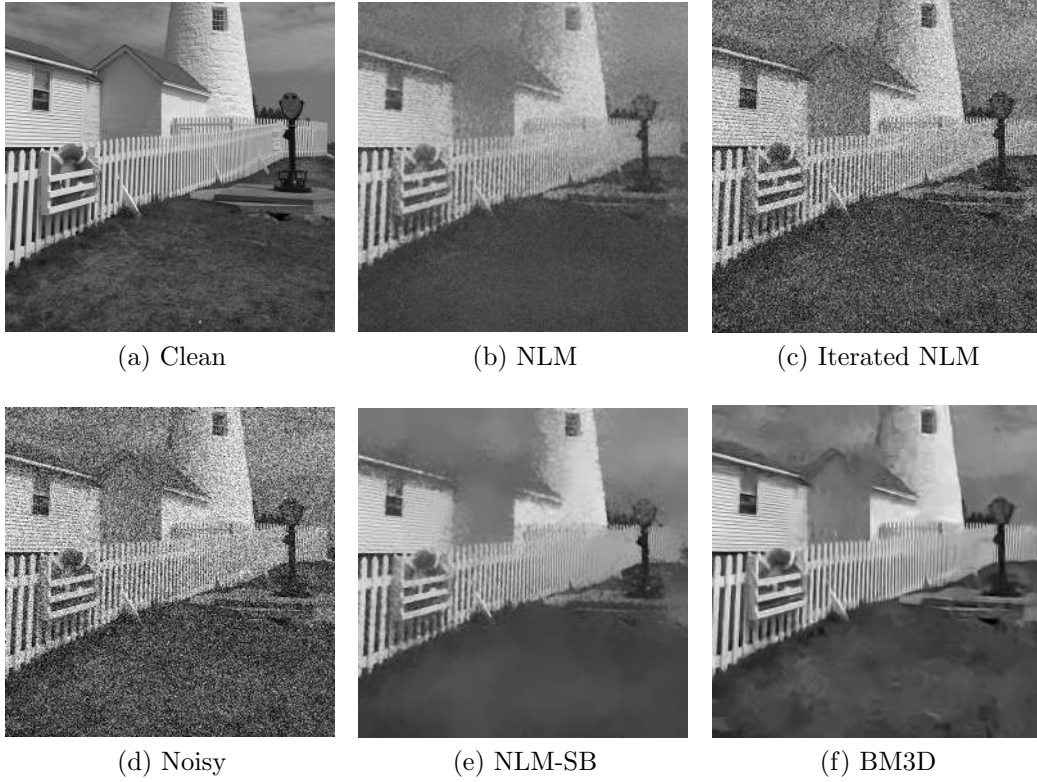
Figure 33: *lighthouse*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
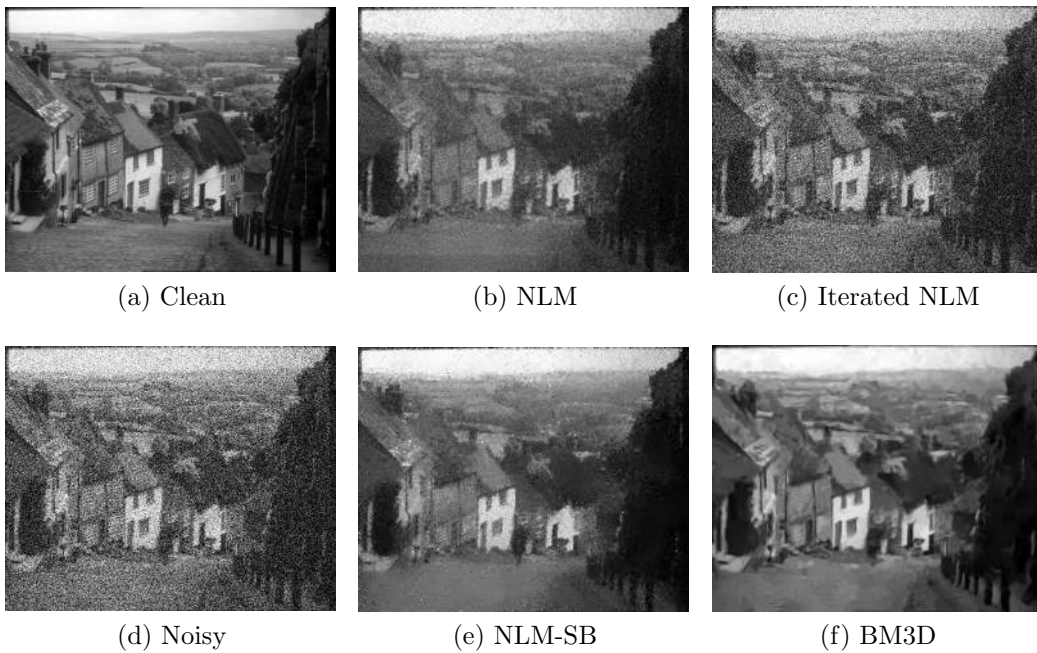
Figure 34: *goldhill*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM
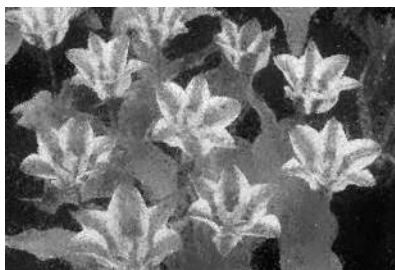
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 35: *houses*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

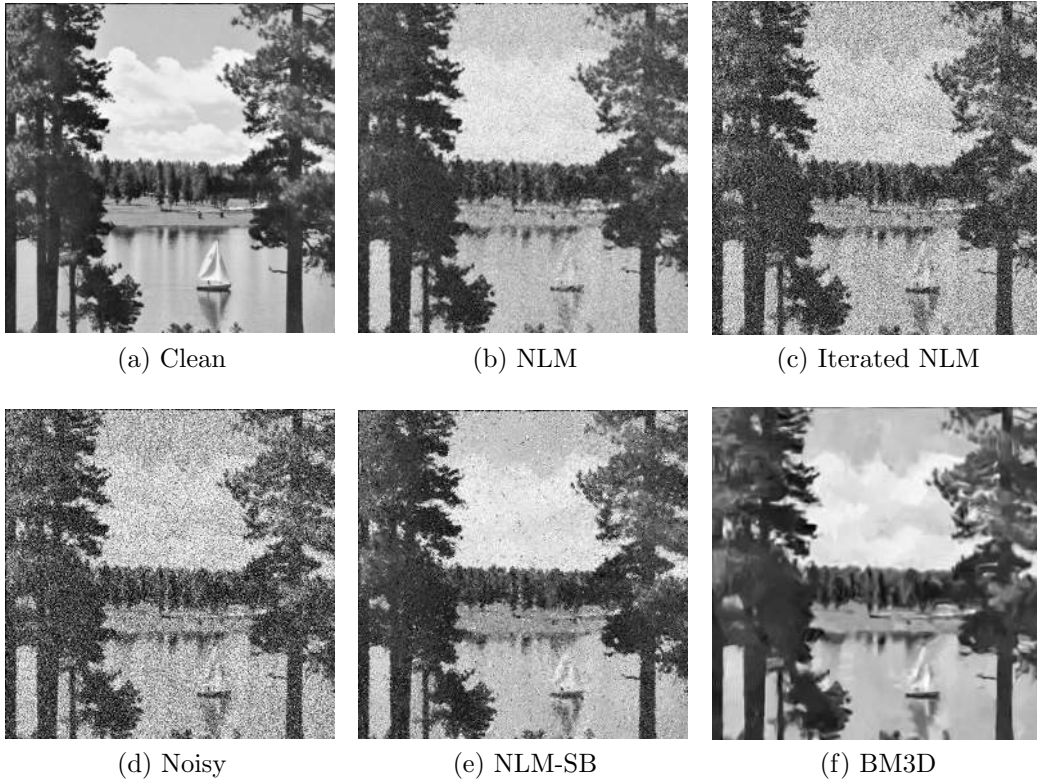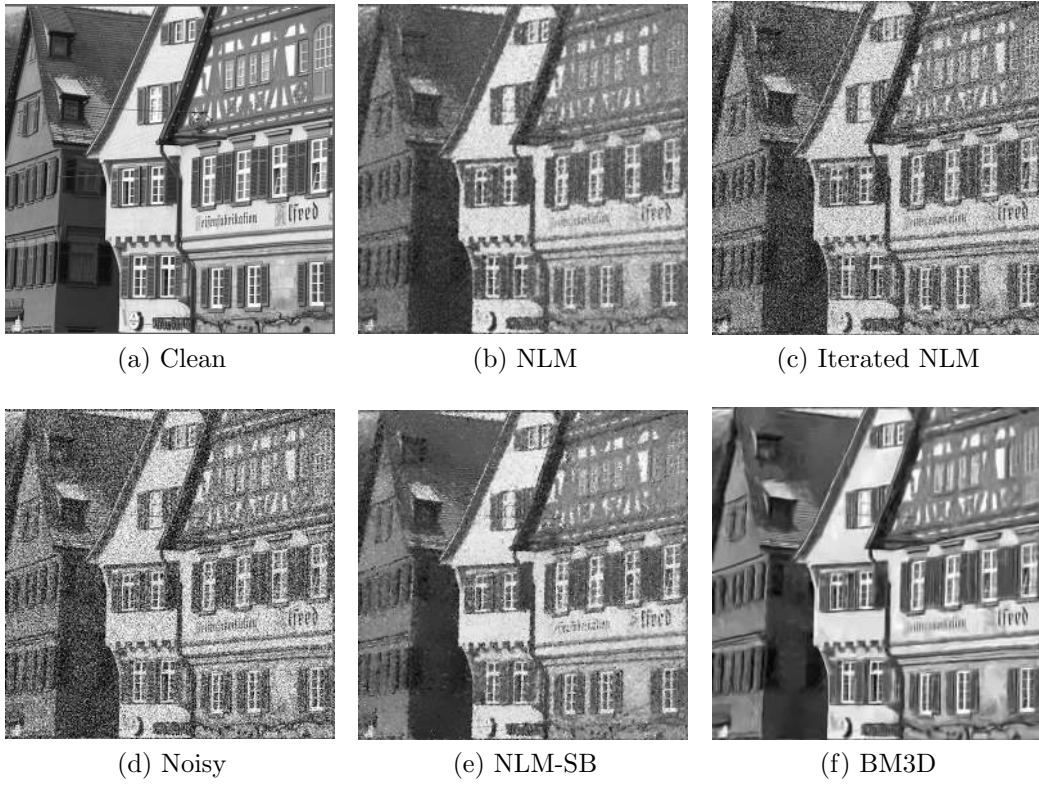(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 36: *girlface*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 37: *girl*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 38: *crowd*, SNR=0.75

(a) Clean　　　　　　(b) NLM　　　　　　(c) Iterated NLM

(d) Noisy　　　　　　(e) NLM-SB　　　　　　(f) BM3D
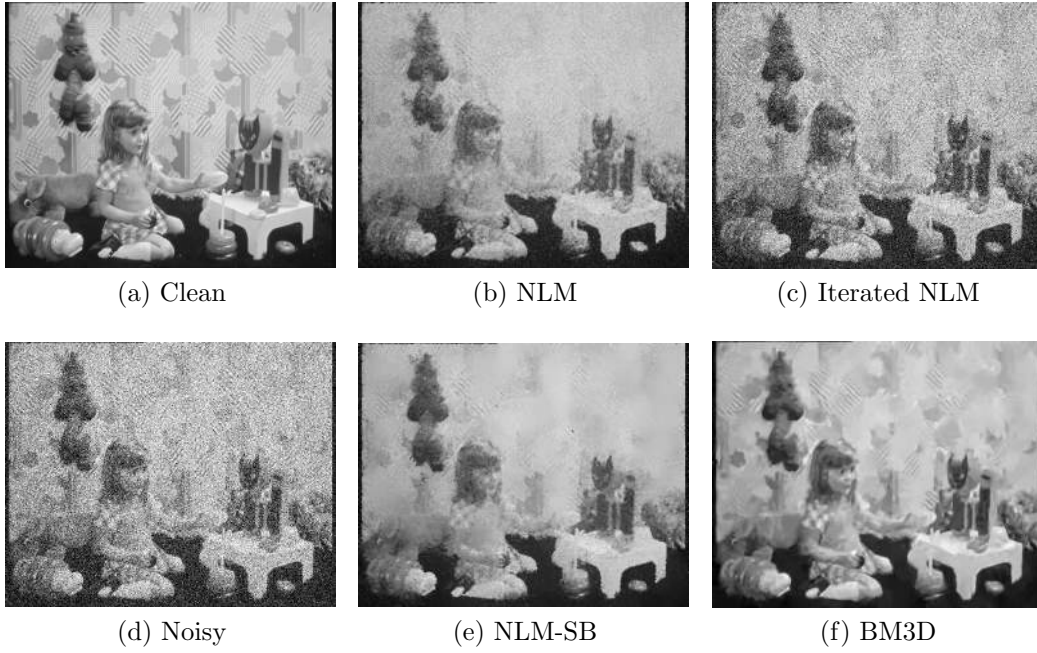
Figure 39: *flower*, SNR=0.75
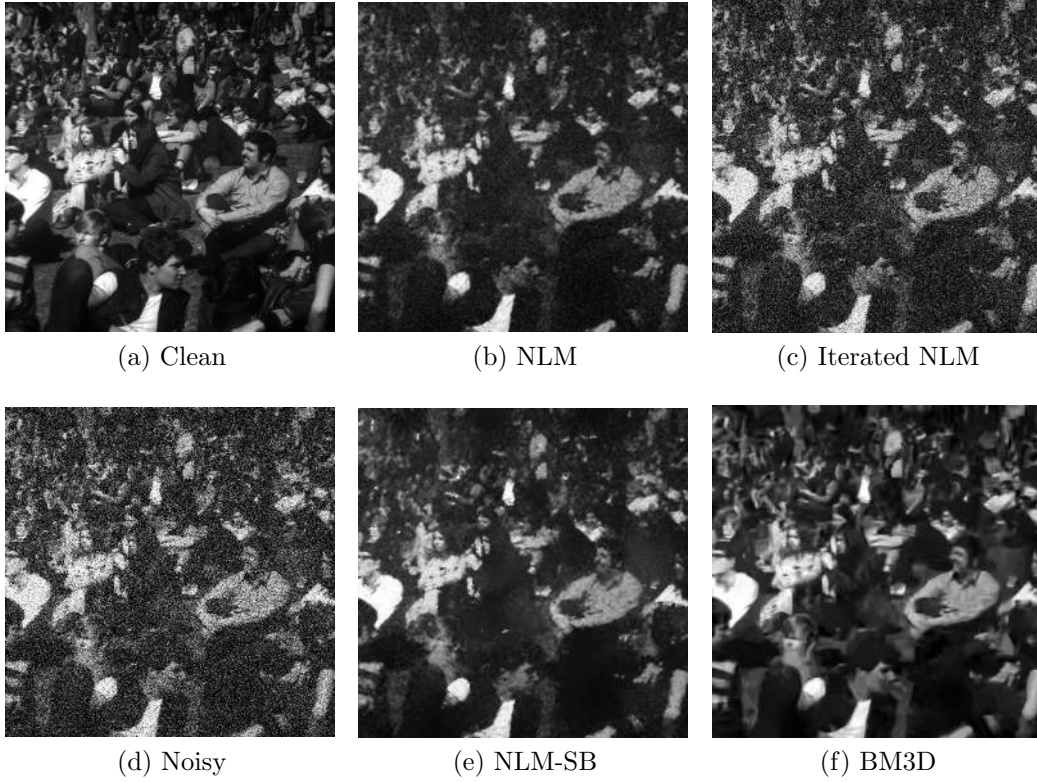
(a) Clean　　　　　　(b) NLM　　　　　　(c) Iterated NLM
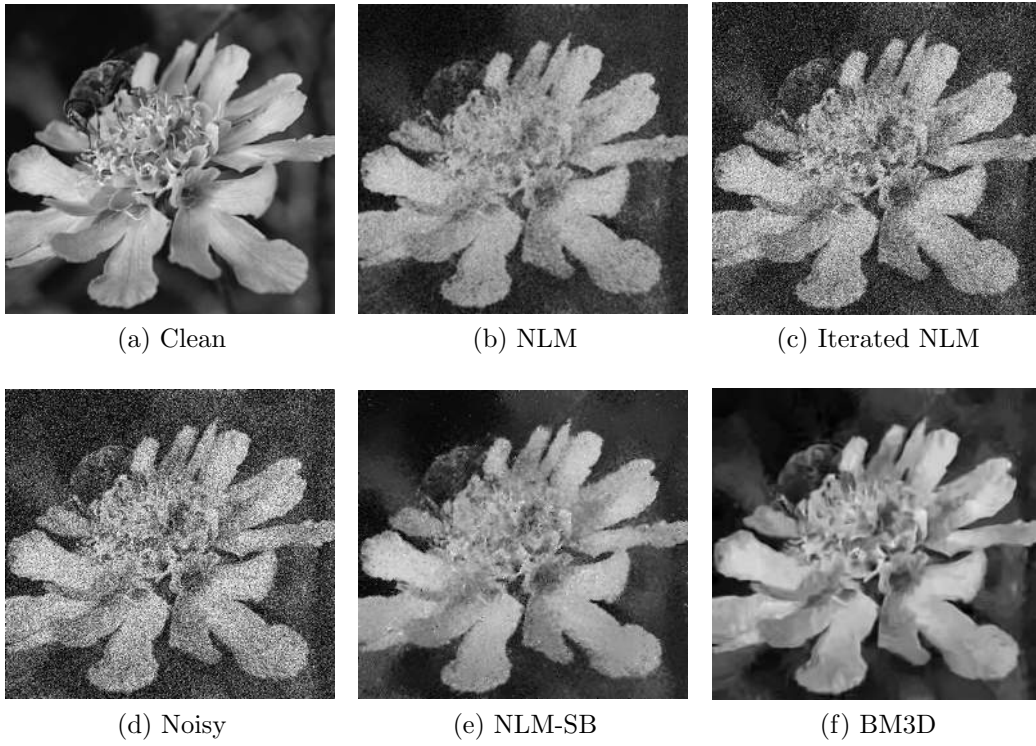
(d) Noisy　　　　　　(e) NLM-SB　　　　　　(f) BM3D

Figure 40: *clown*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM
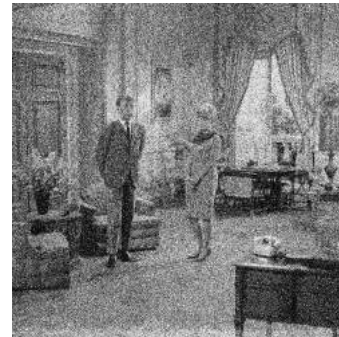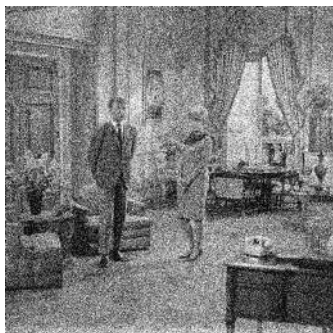
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 41: *couple*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
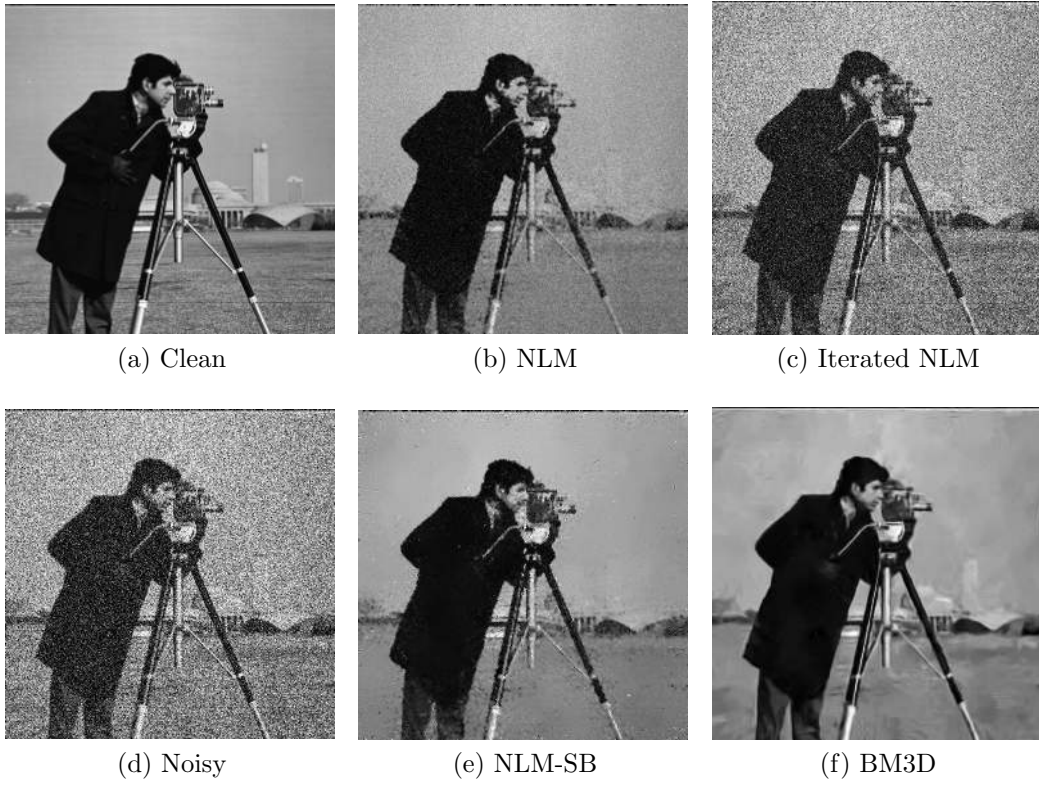
Figure 42: *cameraman*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
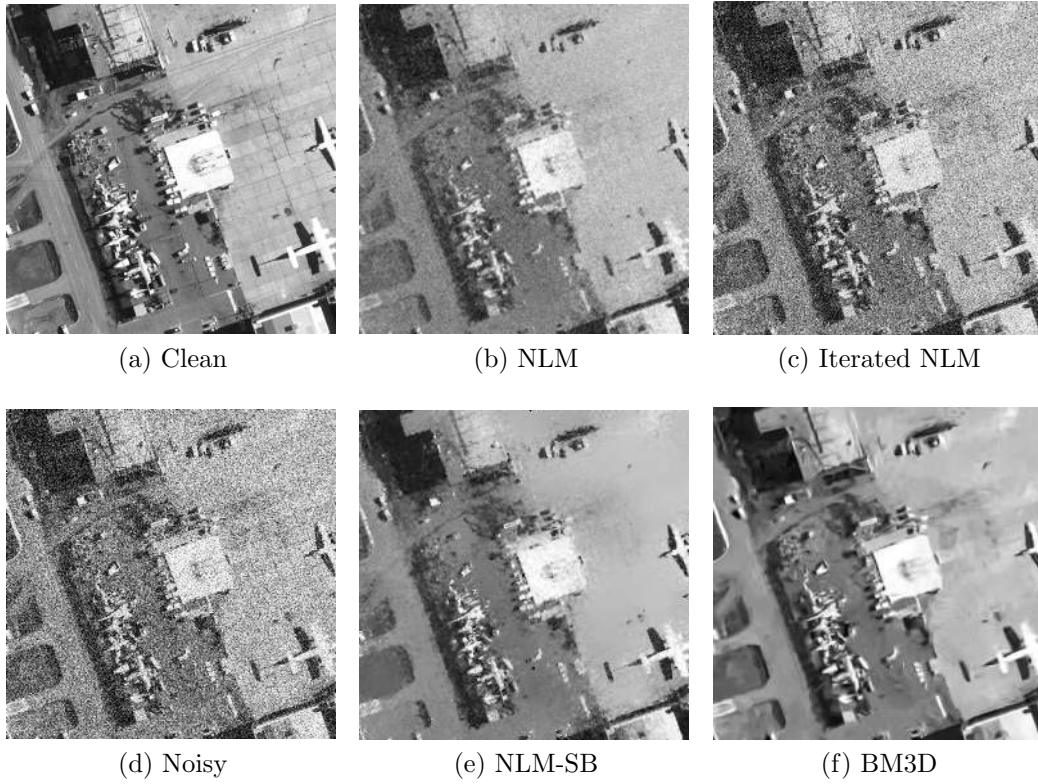
Figure 43: *airfield*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 44: *boats*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 45: *cat*, SNR=0.75

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 46: *zelda*, SNR=0.75

4 Comparisons with SNR=1

(a) Clean

(b) NLM

(c) Iterated NLM

(d) Noisy
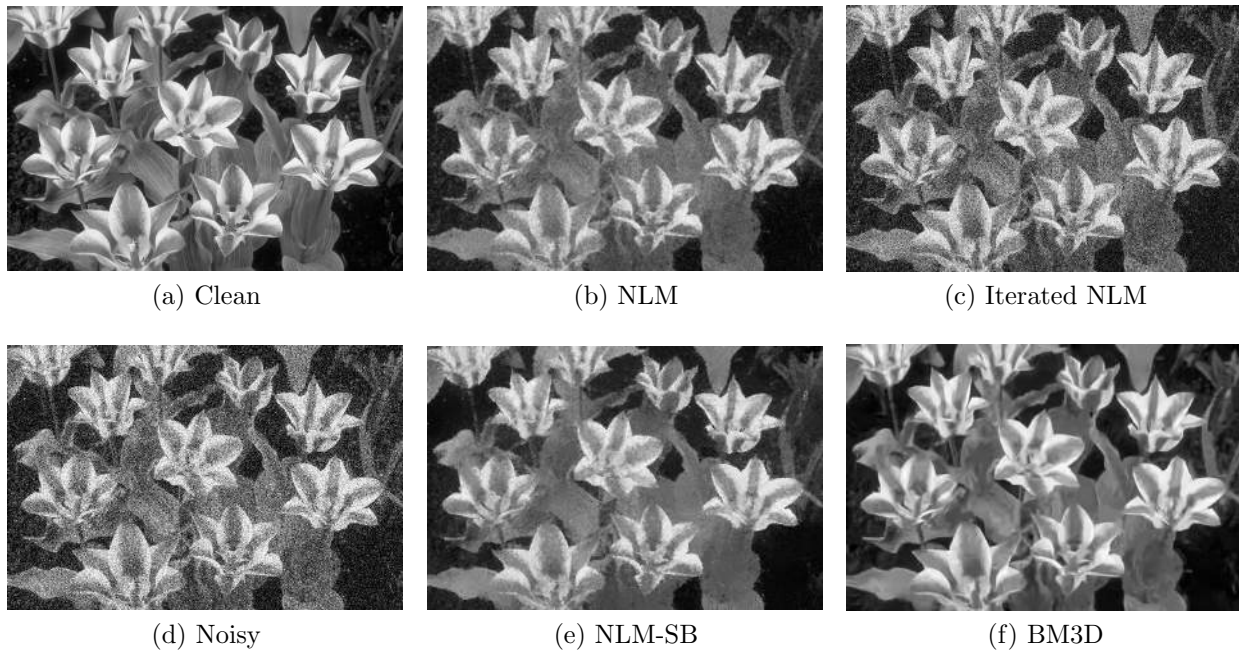
(e) NLM-SB

(f) BM3D

Figure 47: *tulips*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 48: *yacht*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
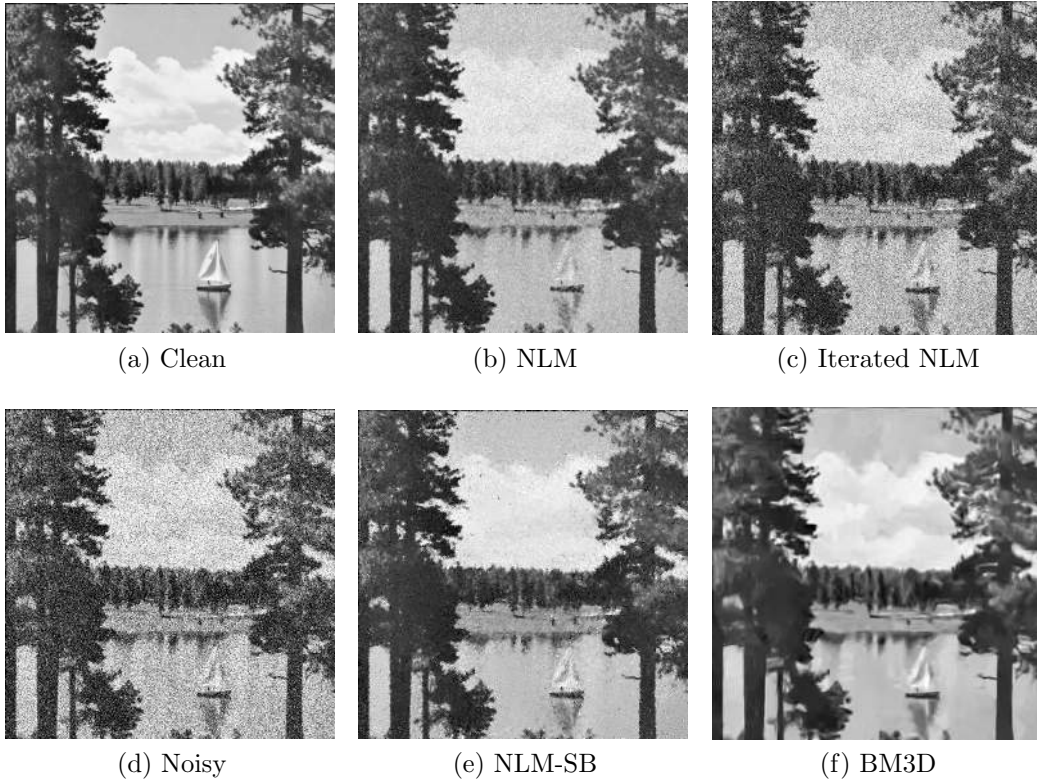
Figure 49: *sailboat*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM
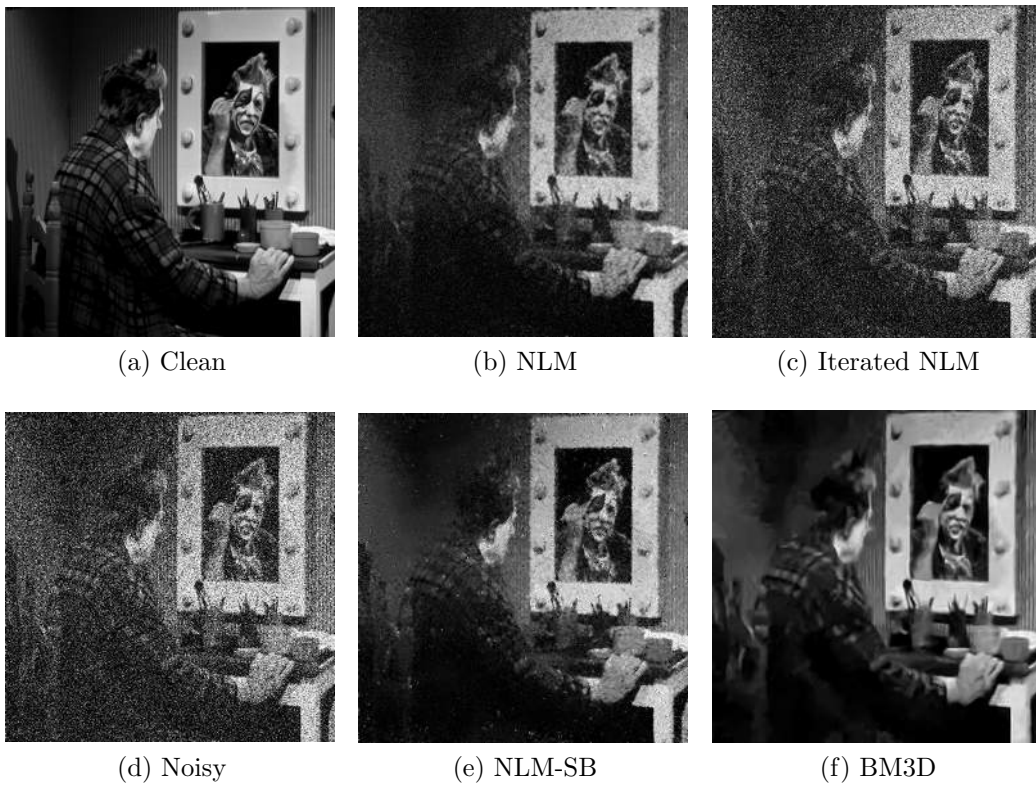
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 50: *soccer*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 51: *pens*, SNR=1.00
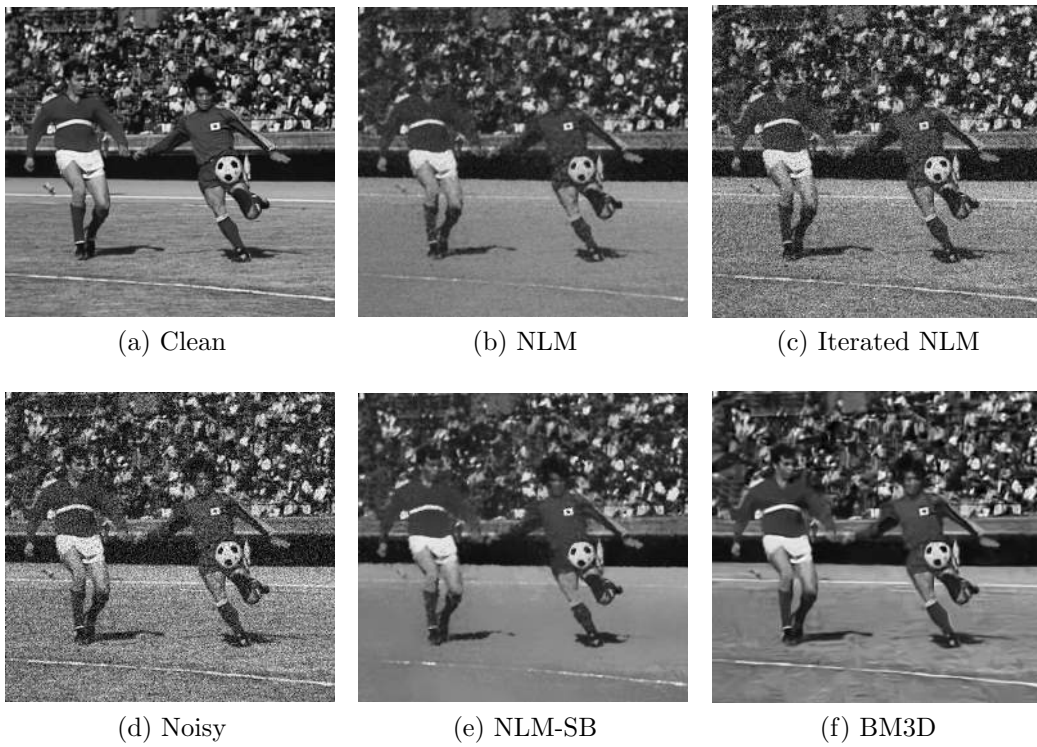
(a) Clean   (b) NLM   (c) Iterated NLM
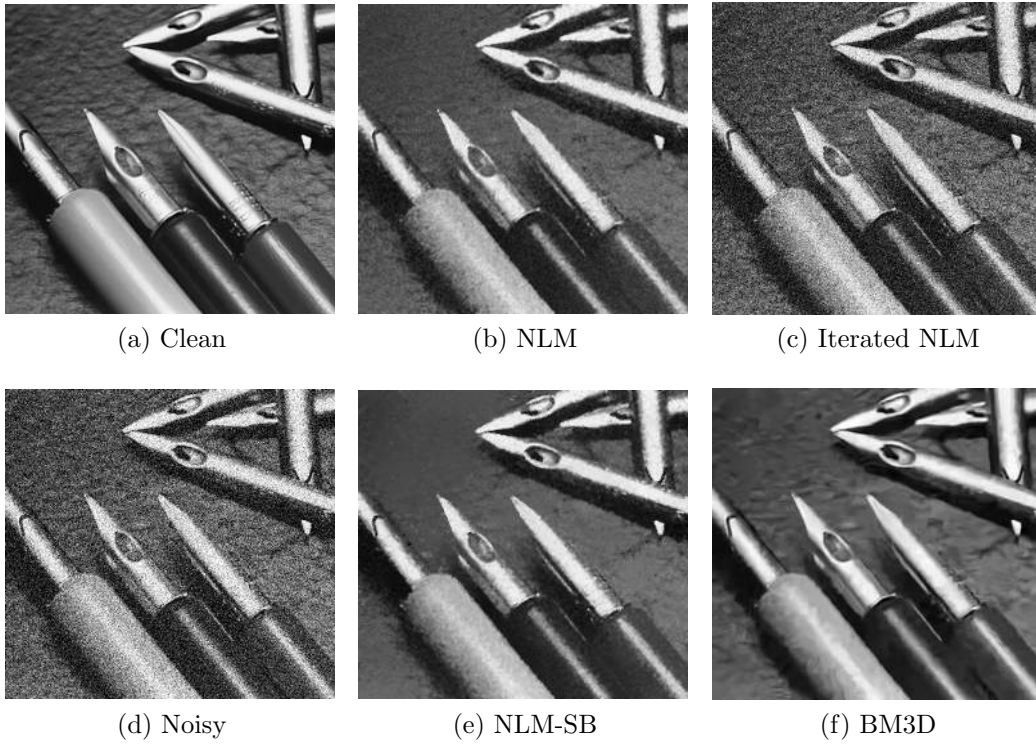
(d) Noisy   (e) NLM-SB   (f) BM3D
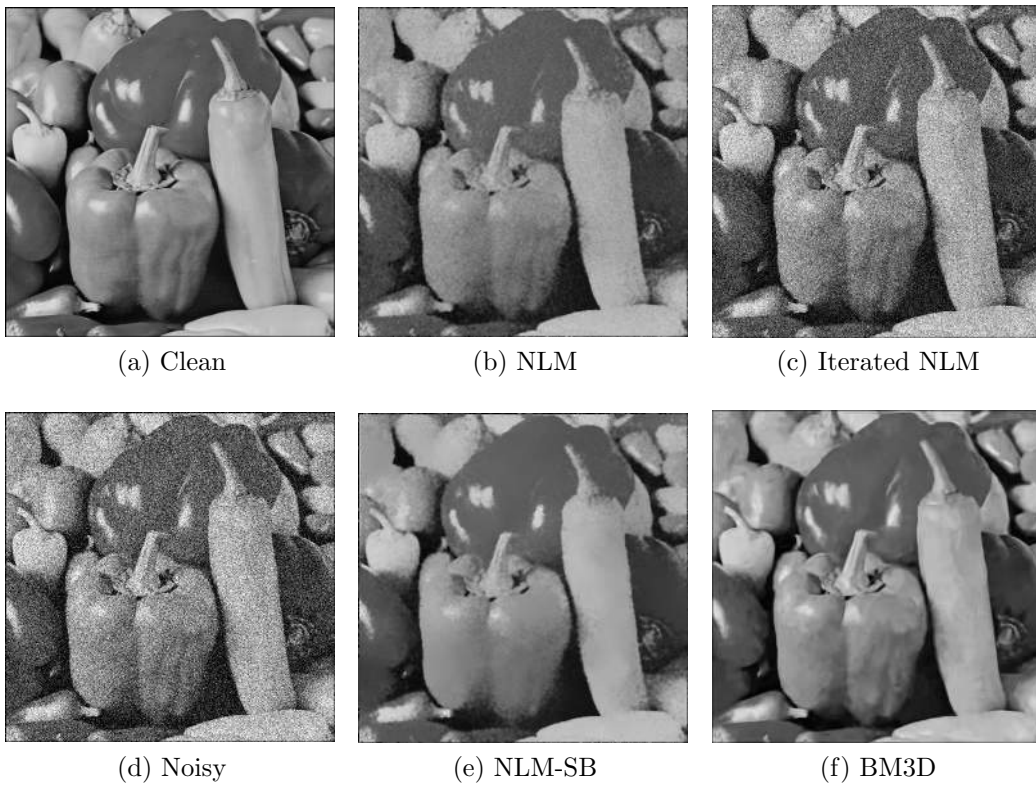
Figure 52: *peppers*, SNR=1.00

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D
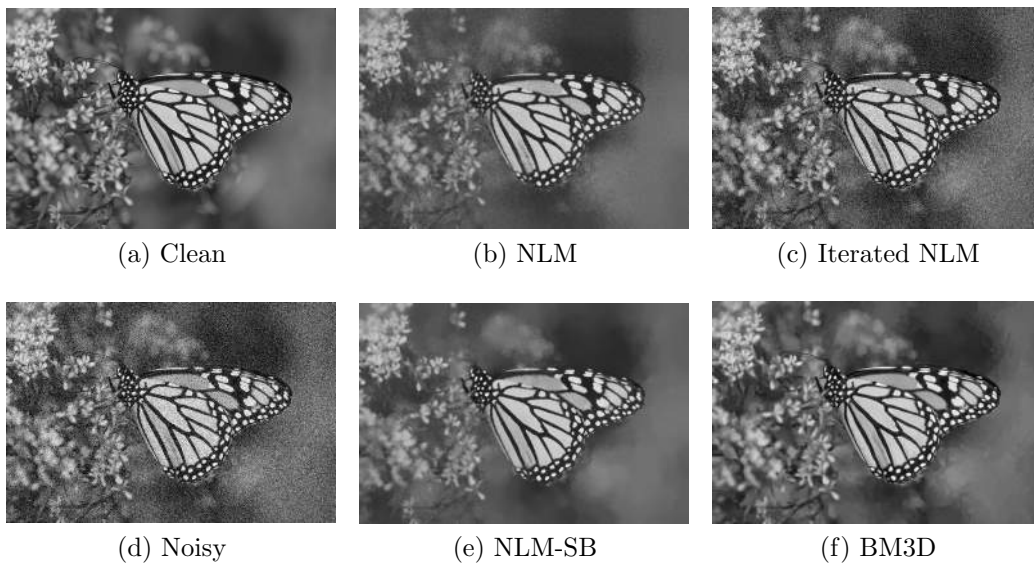
Figure 53: *monarch*, SNR=1.00

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D
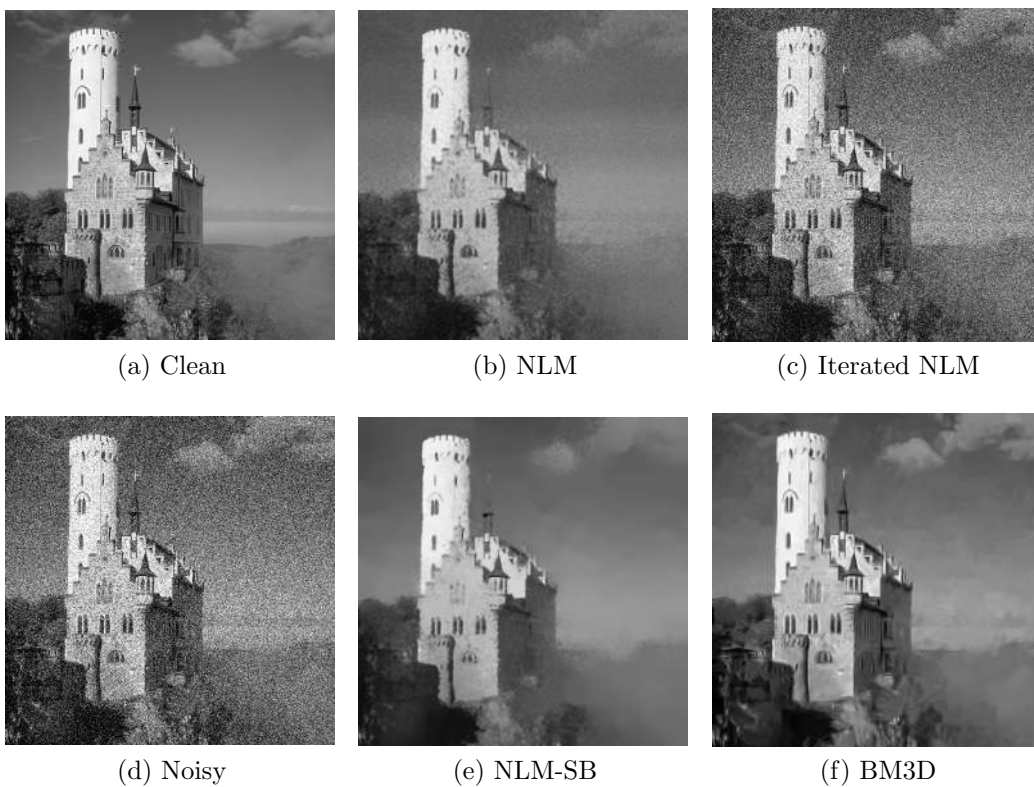
Figure 54: *Lichtenstein*, SNR=1.00

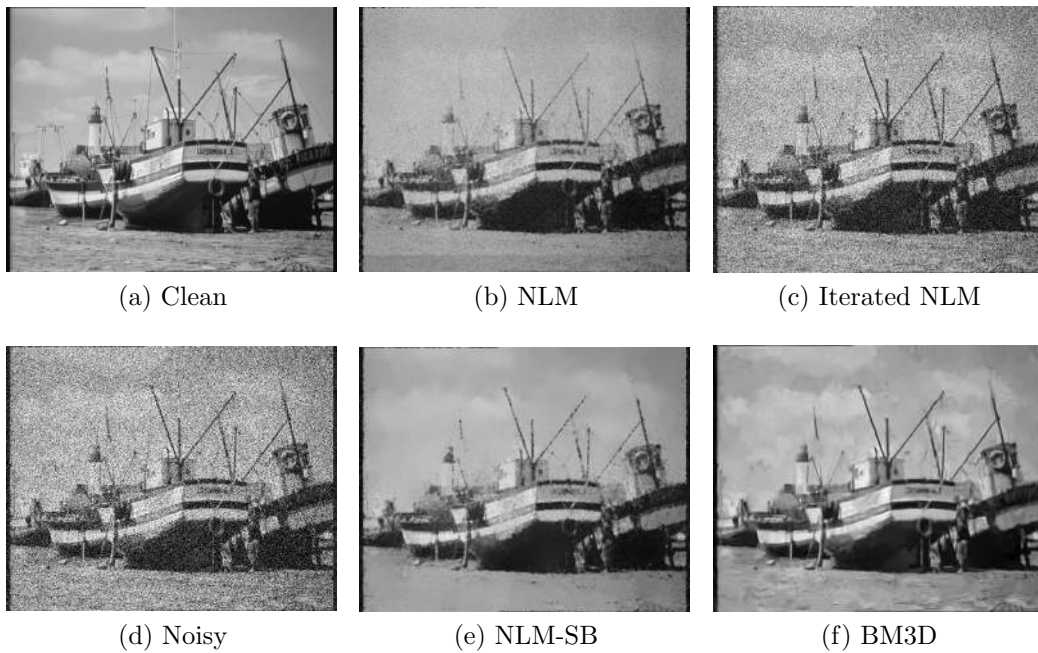(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
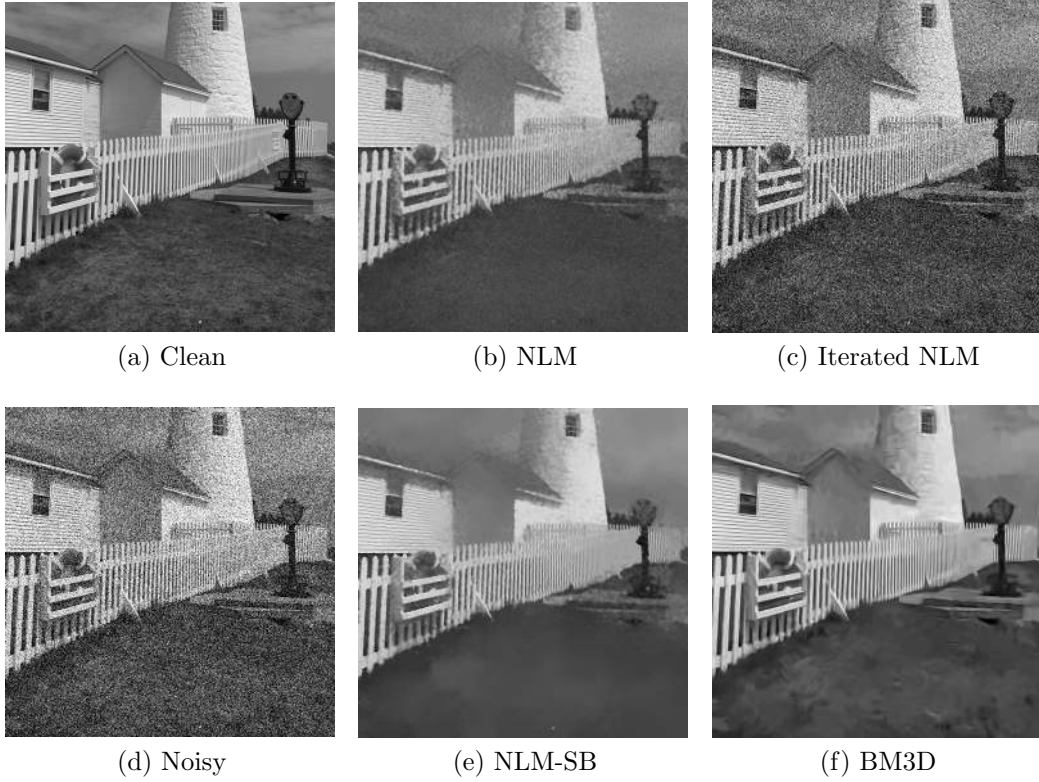
Figure 55: *lighthouse*, SNR=1.00
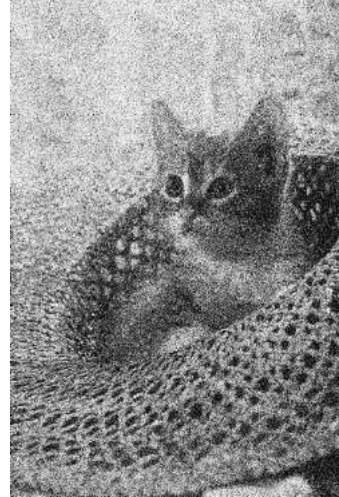

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
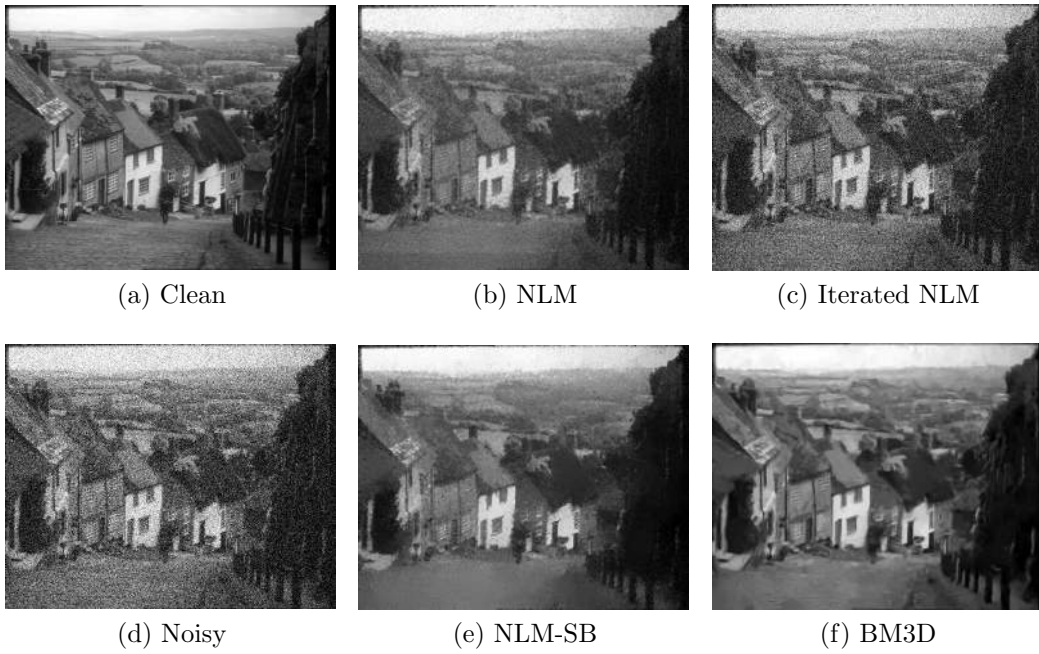
Figure 56: *goldhill*, SNR=1.00

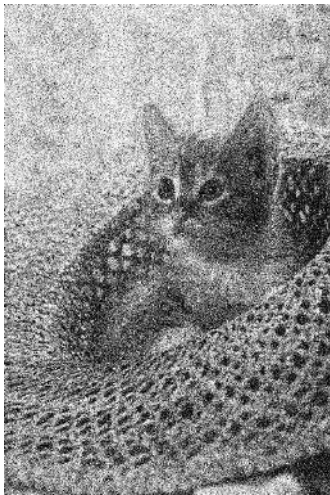(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 57: *houses*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
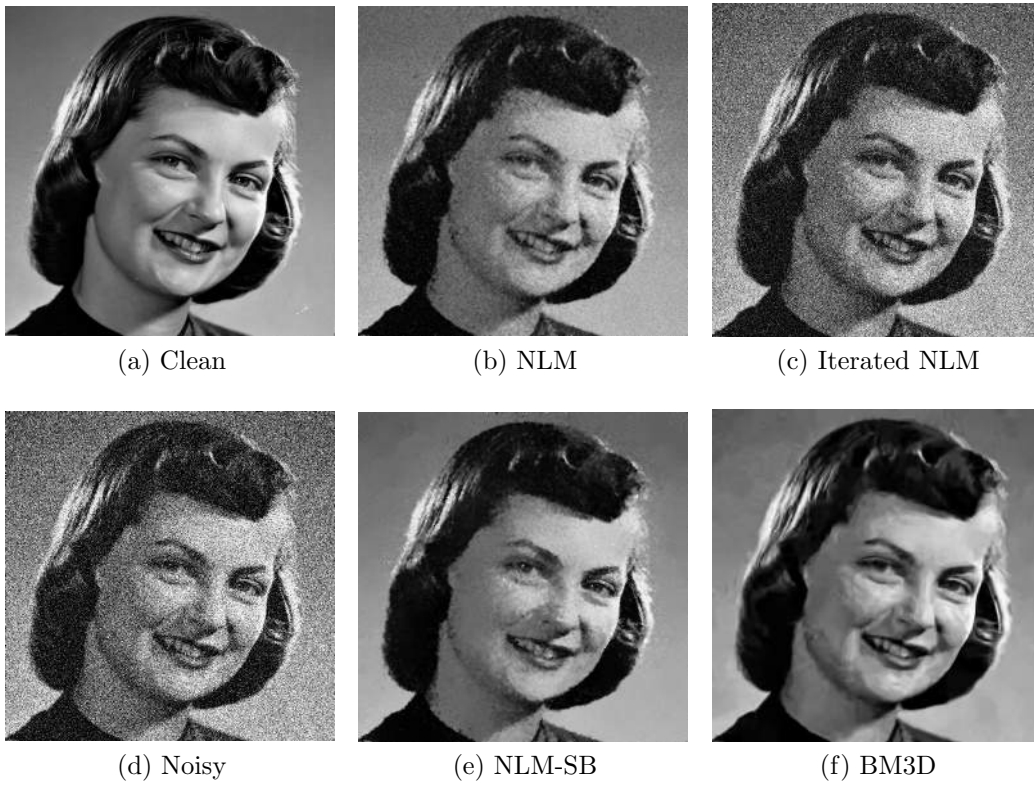
Figure 58: *girlface*, SNR=1.00

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D

Figure 59: *girl*, SNR=1.00

(a) Clean (b) NLM (c) Iterated NLM

(d) Noisy (e) NLM-SB (f) BM3D

Figure 60: *crowd*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
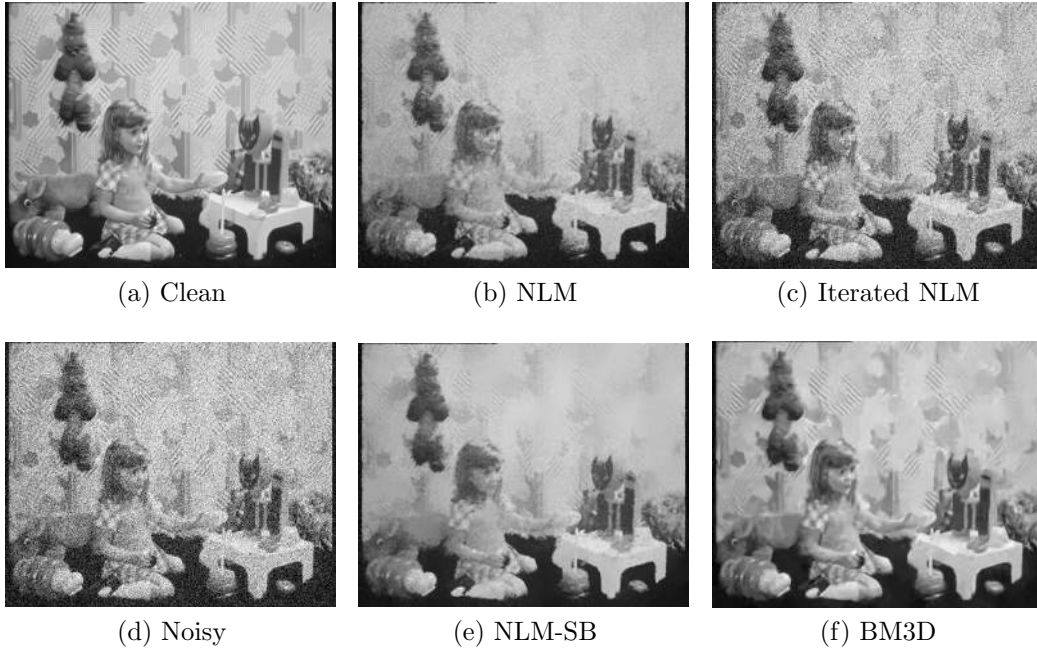
Figure 61: *flower*, SNR=1.00
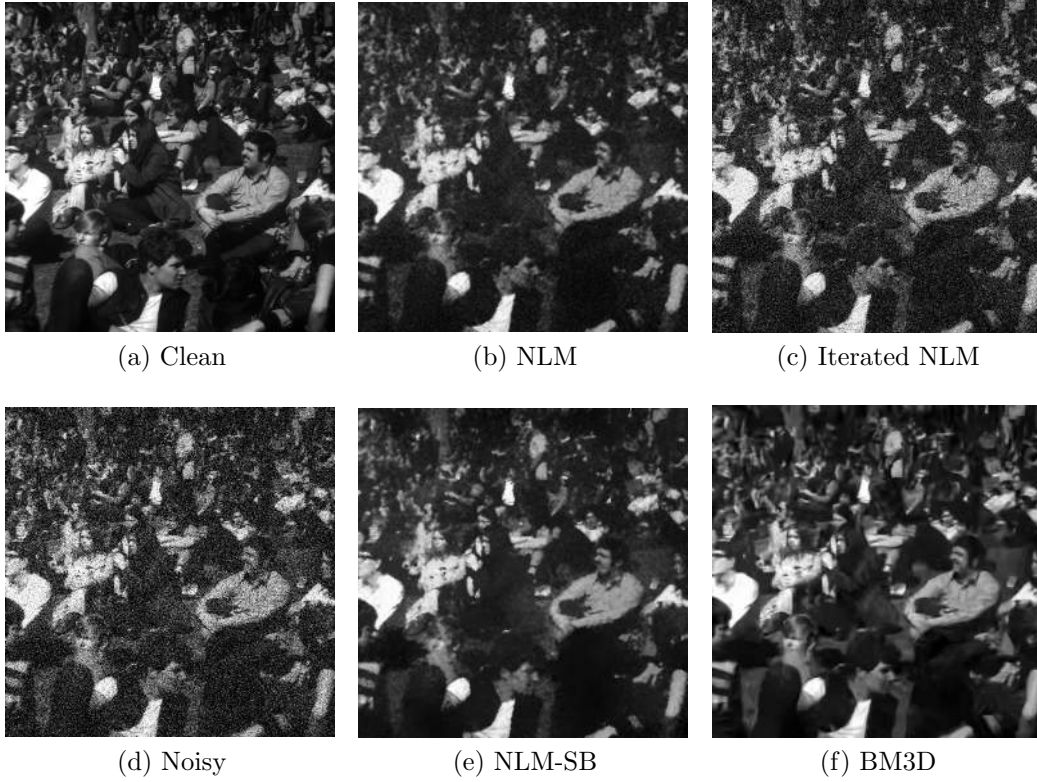
(a) Clean   (b) NLM   (c) Iterated NLM
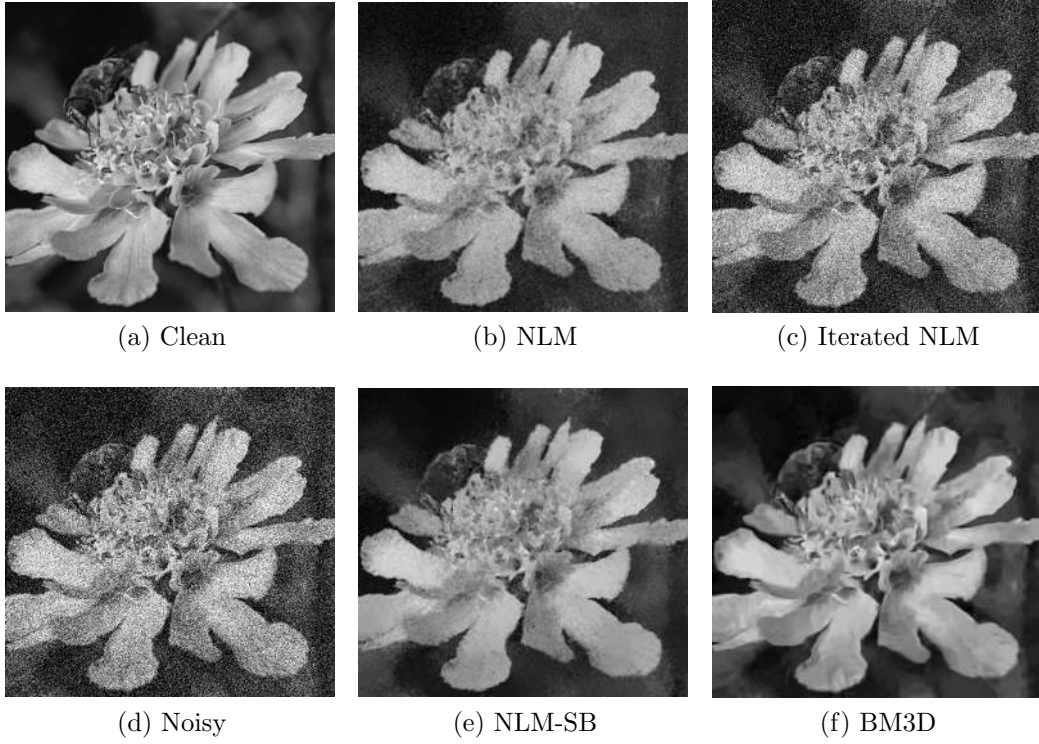
(d) Noisy   (e) NLM-SB   (f) BM3D
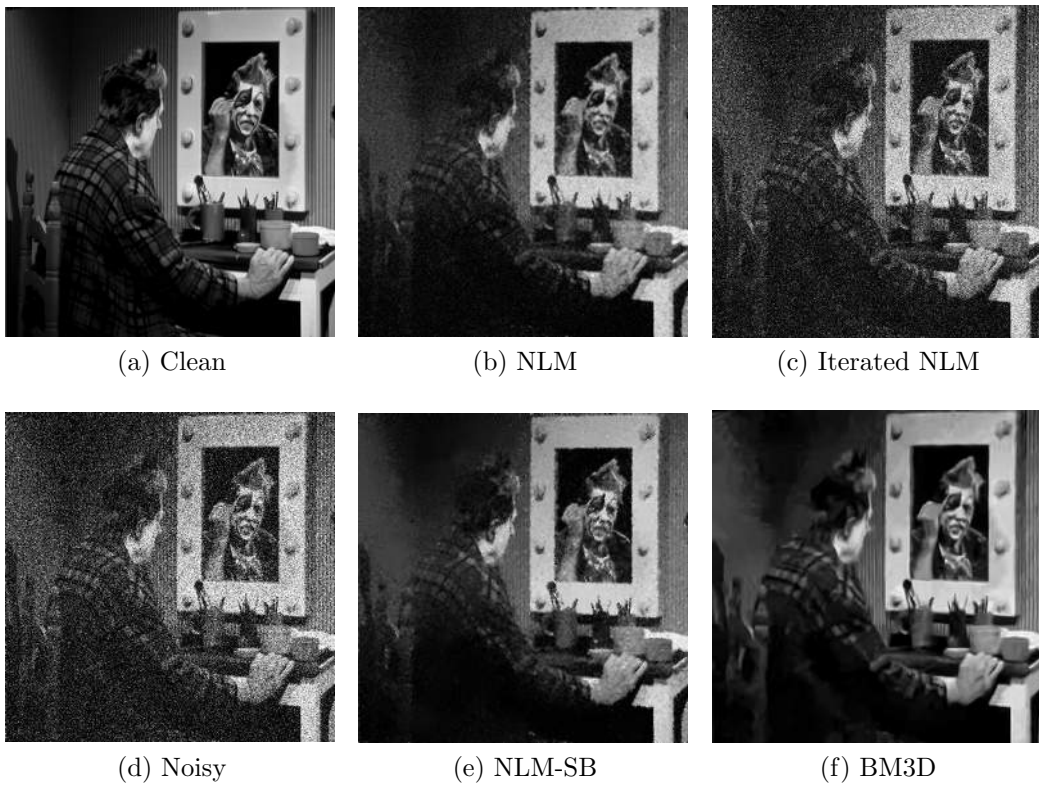
Figure 62: *clown*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM
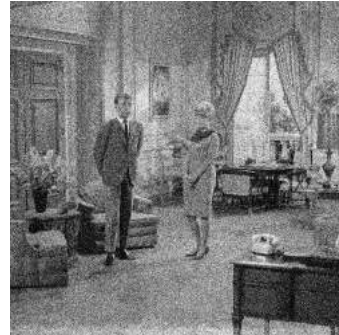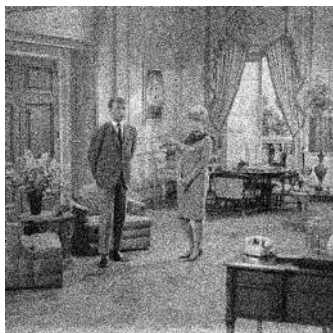
(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 63: *couple*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D
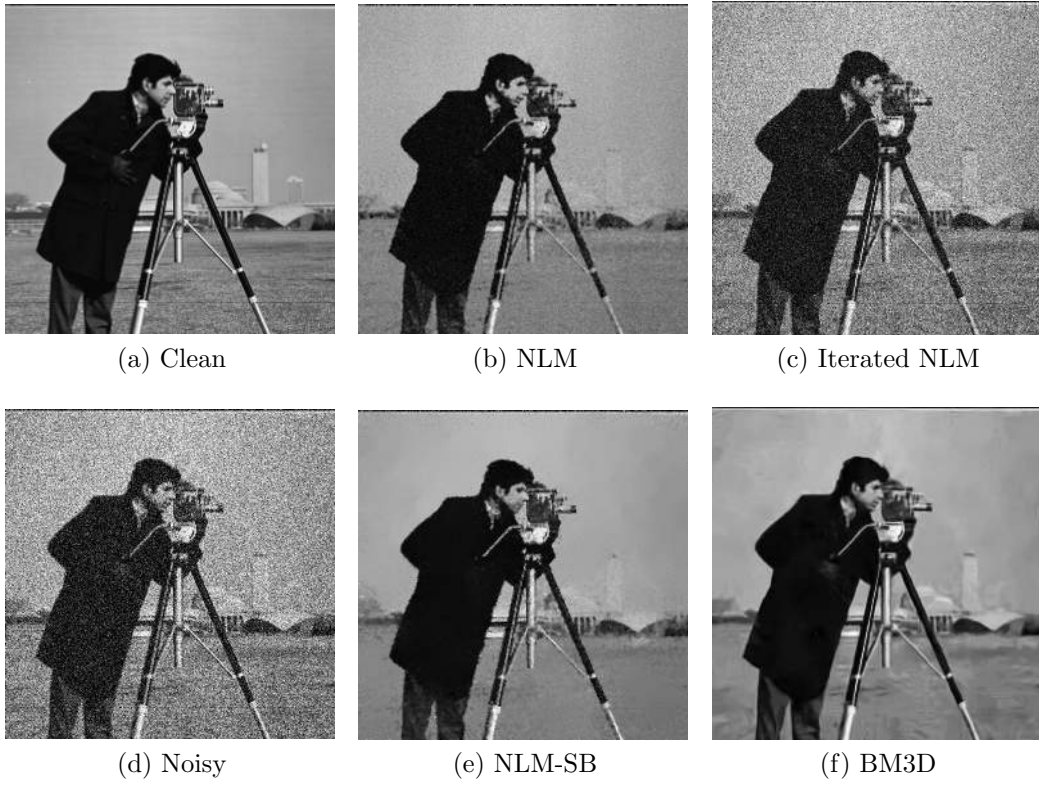
Figure 64: *cameraman*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 65: *airfield*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 66: *boats*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 67: *cat*, SNR=1.00

(a) Clean   (b) NLM   (c) Iterated NLM

(d) Noisy   (e) NLM-SB   (f) BM3D

Figure 68: *zelda*, SNR=1.00

Table of comparisons − PSNR results

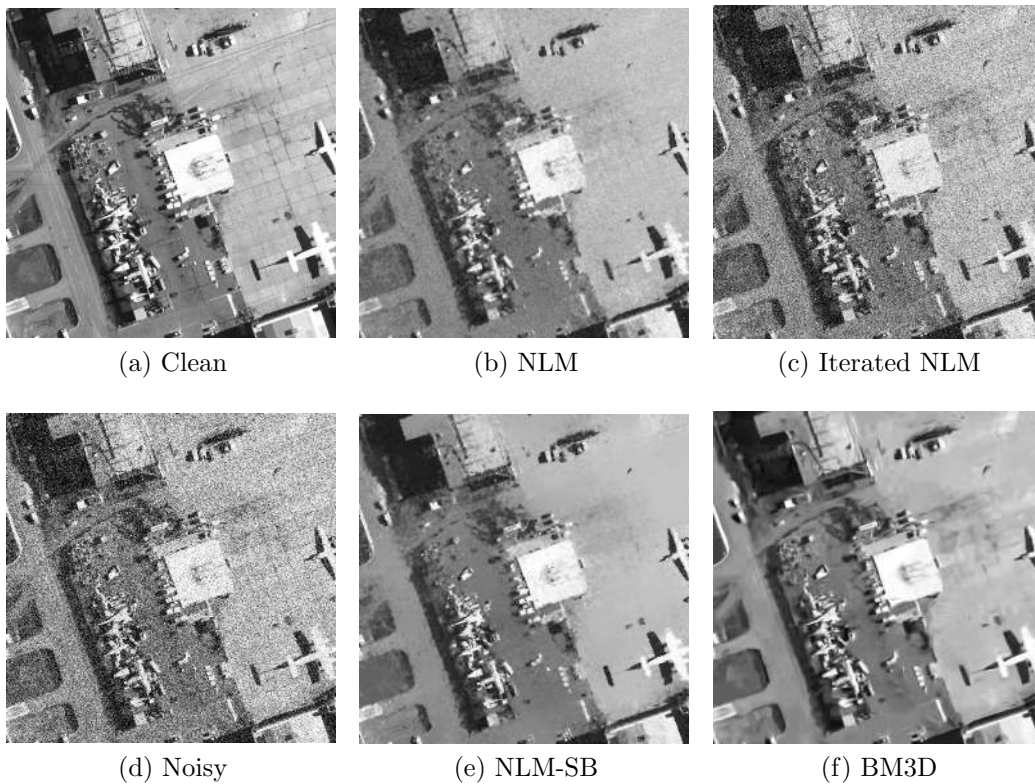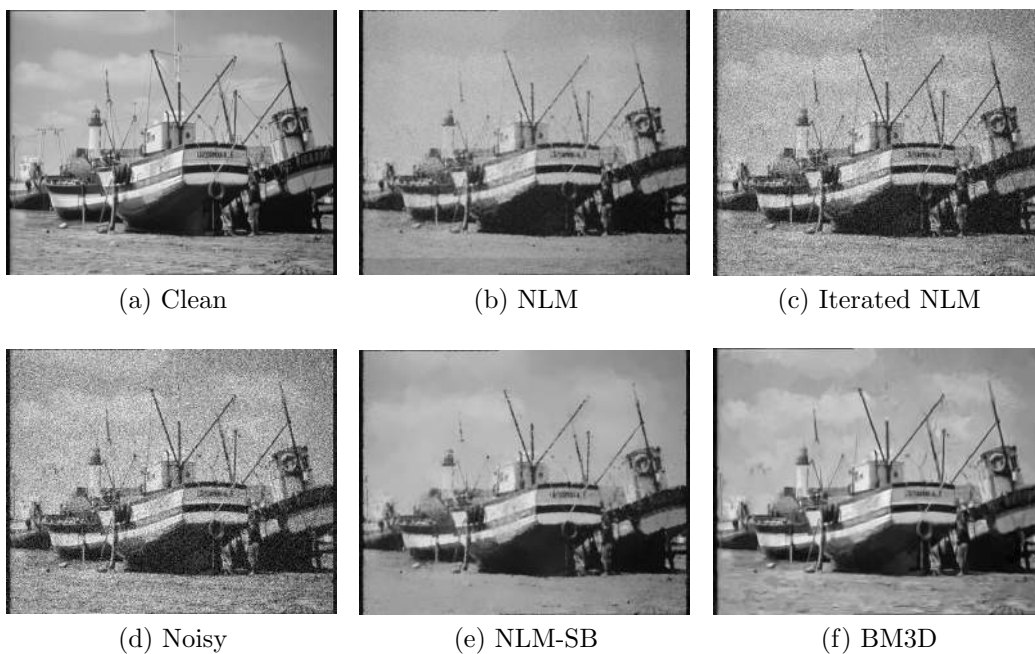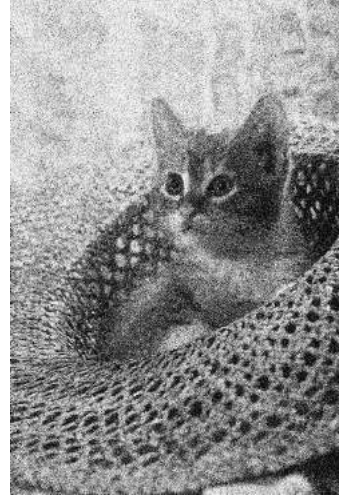| Noise level	SNR=0.5				SNR=0.75				SNR=1			
Image	Iterated-NLM	NLM	NLM-SB	BM3D	Iterated-NLM	NLM	NLM-SB	BM3D	Iterated-NLM	NLM	NLM-SB	BM3D
airfield	11.06	18.31	19.43	20.99	13.44	19.80	20.83	22.45	15.47	21.47	22.27	24.22
boats	11.29	17.82	21.56	23.90	13.70	21.02	23.64	25.72	15.75	23.53	24.97	26.12
cameraman	10.86	16.84	21.44	24.06	13.14	20.13	22.68	25.95	15.15	23.39	24.85	23.49
cat	10.52	18.45	16.90	20.85	12.81	18.78	18.03	22.87	14.80	20.39	21.13	27.01
clown	10.78	17.60	19.54	23.59	13.42	18.72	20.74	25.59	15.56	22.61	23.63	27.21
couple	12.52	20.14	20.66	23.93	15.23	21.95	22.45	25.64	17.49	23.29	23.36	26.97
crowd	11.58	18.84	20.36	22.44	14.40	21.75	22.30	24.16	16.60	22.84	23.67	26.90
flower	10.89	17.17	21.27	24.61	13.29	21.25	22.14	26.64	15.31	23.41	25.10	25.43
flowers	11.52	18.95	20.33	22.05	14.13	20.92	22.10	23.64	16.22	22.55	23.23	28.06
girl	11.08	17.59	22.04	24.45	13.49	21.70	23.61	26.29	15.50	23.67	25.31	24.80
girlface	10.81	17.71	21.45	24.79	13.12	20.60	22.58	26.73	15.12	23.38	25.24	27.62
goldhill	10.80	16.02	20.92	23.43	13.15	21.43	21.72	25.02	15.17	22.58	23.91	27.94
houses	10.73	17.31	16.96	19.49	13.02	18.42	17.86	21.45	15.02	20.01	20.03	26.07
Lichtenstein	12.11	20.51	22.24	24.56	14.69	23.13	24.03	26.04	16.87	24.40	24.87	22.80
lighthouse	11.61	19.00	20.51	23.34	14.08	21.26	22.60	24.95	16.15	22.82	23.67	27.08
monarch	12.51	21.01	21.48	24.73	15.19	22.84	24.09	26.71	17.37	24.60	25.57	26.00
pens	10.98	15.15	20.87	24.04	13.38	21.08	22.01	25.98	15.40	23.18	24.29	28.15
peppers	11.61	18.23	21.41	25.29	14.09	20.65	24.26	27.68	16.17	24.30	26.00	27.30
sailboat	10.39	17.70	14.24	21.14	12.66	21.15	16.38	23.13	14.61	20.64	19.76	29.30
soccer	11.60	18.40	19.77	21.92	14.12	20.95	21.92	23.88	16.25	22.66	23.09	24.27
tulips	10.80	18.19	19.37	22.82	13.13	20.71	20.38	24.80	15.13	22.26	23.10	25.32
yacht	11.15	15.88	20.30	22.72	13.52	21.99	22.25	24.86	15.55	22.49	23.64	26.39
zelda	11.53	19.23	21.77	24.98	13.96	22.16	24.07	26.96	16.02	24.25	25.52	28.32
AVERAGE	11.25	18.09	20.21	23.22	13.70	20.97	21.85	25.09	15.77	22.81	23.75	26.38