A machine learning approach for non-blind image deconvolution

Supplementary material

Contents

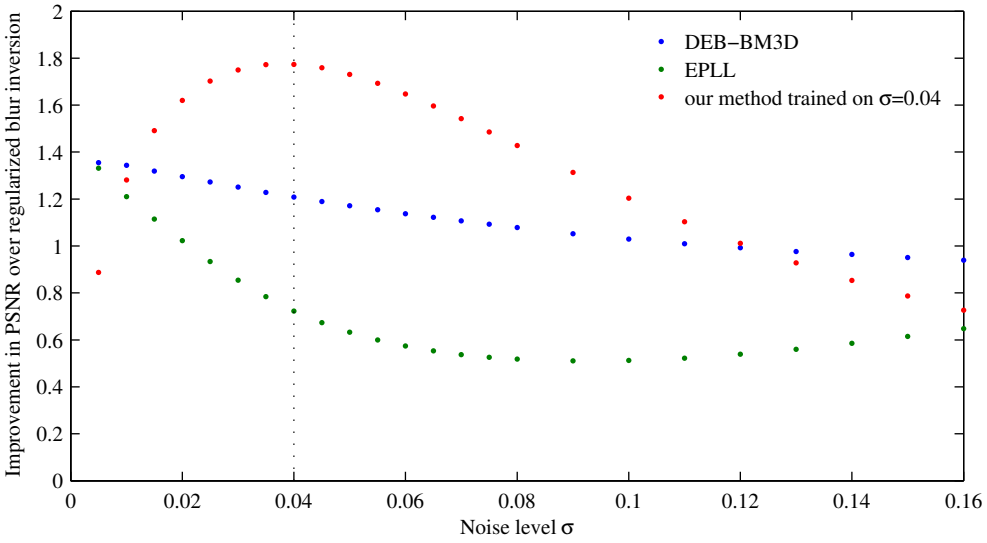
1 Overview

Section 2 shows the behavior of our method for a MLP trained on a specific noise level, but then applied for deconvolution at a different noise level.

Section 3 presents more results for the removal of defocus blur in a real-world setting. In the paper, we compare the result achieved with our MLP against DEB-BM3D, where we first de-mosaicked and then deconvolved. Here, we show additionally the result obtained by DEB-BM3D when first deconvolving and then de-mosaicking. Also, we show the result obtained using Krishnan *et al.*, where we first deconvolved, then de-mosaicked. We find the result obtained with DEB-BM3D by first de-mosaicking, then deconvolving to be the best compromise between sharpness and artifacts. The result obtained with Krishan *et al.*looks grainy.

In the remaining five sections we show additional results for each of the five scenarios described in the paper. For each scenario, we show results obtained on 21 images. For each image, we show the ground truth image, the corrupted (blurry and noisy) image, the result of the direct deconvolution, the results obtained by our MLP, and the results obtained by five competing methods (we left out the FoE-based method due to prohibitive computation times). We selected the 21 images as follows: We compared the results achieved by IDD-BM3D to our method on scenario (d). We sorted the 500 images in the Berkeley segmentation dataset in order of increasing improvement of our method over IDD-BM3D. From this sorting, we picked 21 images in roughly equally spaced intervals, beginning with the case where the MLP performs worst.

2 Noise dependence



Behavior of the MLP from scenario (c) at different noise levels, evaluated on 11 standard test images for denoising. The plot shows the improvement over the regularized blur inversion. DEB-BM3D and EPLL take only the noise level as a parameter and should be optimal at every noise level. The MLP was trained only on $\sigma = 0.04$, where its performance peaks, for other values it degrades slowly.

3 Real-world example

Defocused Image

Direct Deconvolution

Krishnan *et al.*(deconv., then de-mosaick)

DEB-BM3D (deconv., then de-mosaick)

DEB-BM3D (de-mosaick, then deconv.)

MLP

4 Scenario (a)

4.1 Image “119082” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
20.89 dB

Direct Deconvolution
22.34 dB

EPLL
23.36 dB

Krishnan *et al.*
23.56 dB

Levin *et al.*
23.31 dB

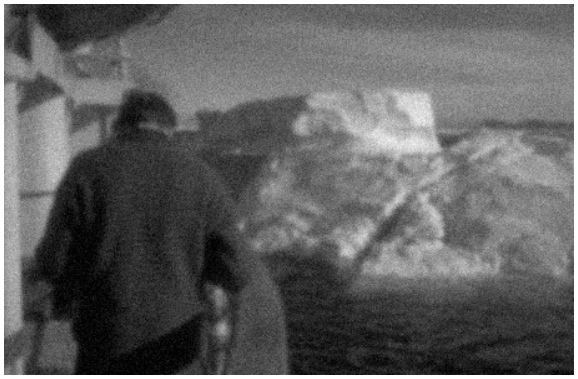
DEB-BM3D
23.86 dB

IDD-BM3D
24.39 dB

MLP
24.63 dB

4.2 Image “188005” in scenario (a): small Gaussian blur with strong noise

Ground Truth



Corrupted
25.09 dB

Direct Deconvolution
25.27 dB

EPLL
27.96 dB

Krishnan *et al.*
28.13 dB

Levin *et al.*
28.13 dB

DEB-BM3D
28.35 dB

IDD-BM3D
28.42 dB

MLP
28.46 dB

4.3 Image “123074” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
25.20 dB

Direct Deconvolution
25.59 dB

EPLL
28.17 dB

Krishnan *et al.*
28.40 dB

Levin *et al.*
28.43 dB

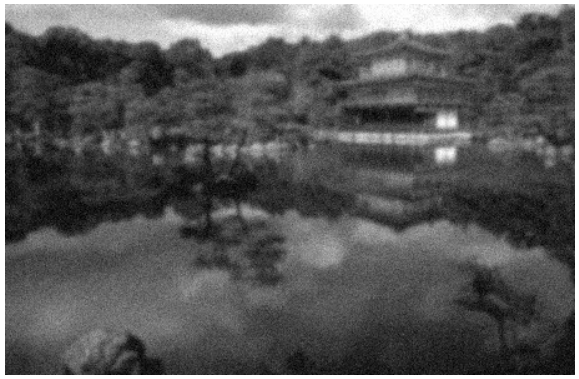
DEB-BM3D
28.57 dB

IDD-BM3D
28.54 dB

MLP
28.64 dB

4.4 Image “65010” in scenario (a): small Gaussian blur with strong noise

Ground Truth



Corrupted
22.81 dB

Direct Deconvolution
23.39 dB

EPLL
24.54 dB

Krishnan *et al.*
24.75 dB

Levin *et al.*
24.69 dB

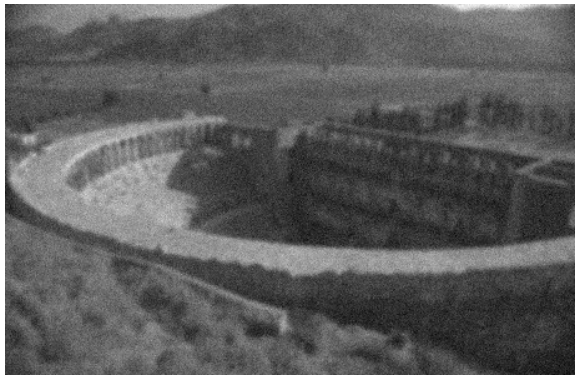
DEB-BM3D
24.87 dB

IDD-BM3D
24.91 dB

MLP
25.08 dB

4.5 Image “166081” in scenario (a): small Gaussian blur with strong noise

Ground Truth



Corrupted
23.99 dB

Direct Deconvolution
24.32 dB

EPLL
26.17 dB

Krishnan *et al.*
26.37 dB

Levin *et al.*
26.33 dB

DEB-BM3D
26.52 dB

IDD-BM3D
26.59 dB

MLP
26.76 dB

4.6 Image “310007” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
24.13 dB

Direct Deconvolution
24.48 dB

EPLL
26.44 dB

Krishnan *et al.*
26.61 dB

Levin *et al.*
26.58 dB

DEB-BM3D
26.81 dB

IDD-BM3D
26.86 dB

MLP
27.02 dB

4.7 Image “65033” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
22.03 dB

Direct Deconvolution
22.85 dB

EPLL
23.39 dB

Krishnan *et al.*
23.68 dB

Levin *et al.*
23.65 dB

DEB-BM3D
23.78 dB

IDD-BM3D
23.84 dB

MLP
24.06 dB

4.8 Image “38092” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
22.99 dB

Direct Deconvolution
23.59 dB

EPLL
24.83 dB

Krishnan *et al.*
25.01 dB

Levin *et al.*
24.97 dB

DEB-BM3D
25.07 dB

IDD-BM3D
25.12 dB

MLP
25.31 dB

4.9 Image “306052” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
23.85 dB

Direct Deconvolution
24.43 dB

EPLL
25.93 dB

Krishnan *et al.*
26.25 dB

Levin *et al.*
26.26 dB

DEB-BM3D
26.32 dB

IDD-BM3D
26.38 dB

MLP
26.52 dB

4.10 Image “41006” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
25.80 dB

Direct Deconvolution
25.75 dB

EPLL
29.71 dB

Krishnan *et al.*
29.76 dB

Levin *et al.*
29.69 dB

DEB-BM3D
29.90 dB

IDD-BM3D
30.06 dB

MLP
30.20 dB

4.11 Image “168084” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
25.80 dB

Direct Deconvolution
25.77 dB

EPLL
29.75 dB

Krishnan *et al.*
29.70 dB

Levin *et al.*
29.69 dB

DEB-BM3D
29.93 dB

IDD-BM3D
30.03 dB

MLP
30.20 dB

4.12 Image “159029” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
22.25 dB

Direct Deconvolution
23.37 dB

EPLL
24.06 dB

Krishnan *et al.*
24.29 dB

Levin *et al.*
24.27 dB

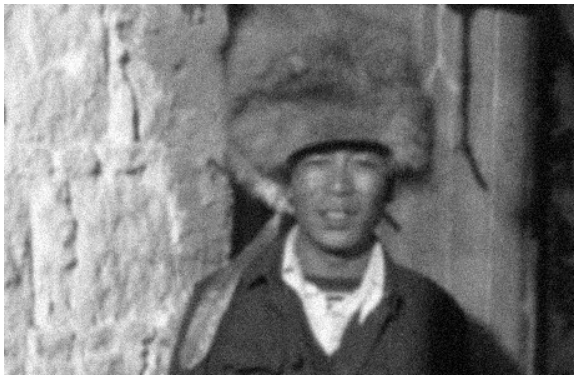
DEB-BM3D
24.40 dB

IDD-BM3D
24.43 dB

MLP
24.65 dB

4.13 Image “15062” in scenario (a): small Gaussian blur with strong noise

Ground Truth



Corrupted
22.31 dB

Direct Deconvolution
23.08 dB

EPLL
24.05 dB

Krishnan *et al.*
24.23 dB

Levin *et al.*
24.16 dB

DEB-BM3D
24.39 dB

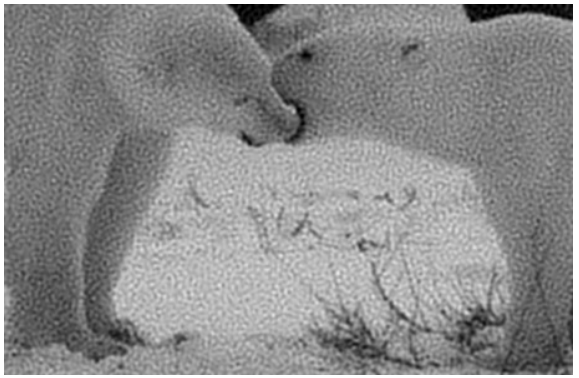
IDD-BM3D
24.51 dB

MLP
24.83 dB

4.14 Image “183055” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
24.95 dB



Direct Deconvolution
24.96 dB

EPLL
27.79 dB

Krishnan *et al.*
27.84 dB

Levin *et al.*
27.83 dB

DEB-BM3D
28.08 dB

IDD-BM3D
28.09 dB

MLP
28.34 dB

4.15 Image “286092” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
24.91 dB

Direct Deconvolution
25.13 dB

EPLL
28.34 dB

Krishnan *et al.*
28.39 dB

Levin *et al.*
28.28 dB

DEB-BM3D
28.51 dB

IDD-BM3D
28.81 dB

MLP
29.02 dB

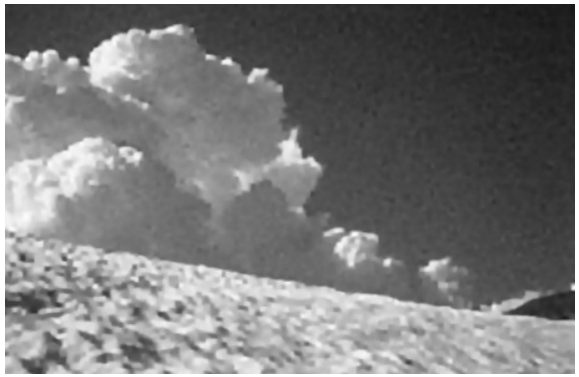
4.16 Image “176039” in scenario (a): small Gaussian blur with strong noise

Ground Truth

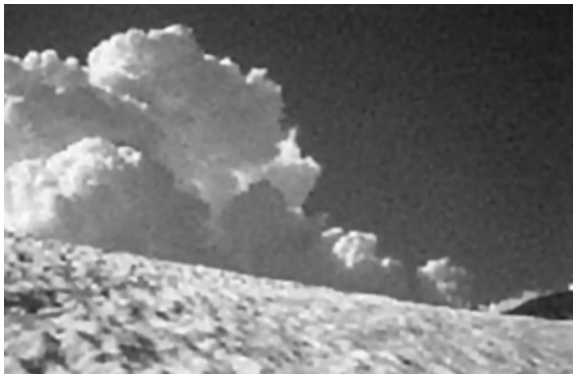
Corrupted
23.81 dB

Direct Deconvolution
24.52 dB

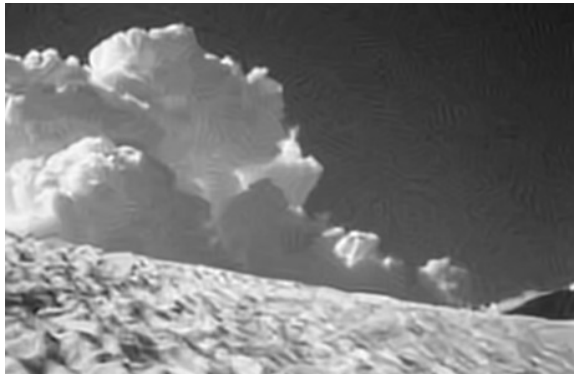
EPLL
26.48 dB



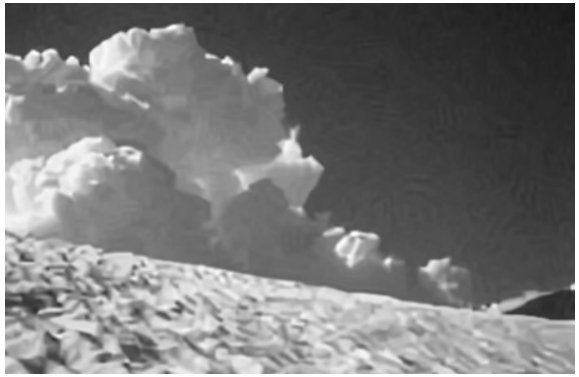
Krishnan *et al.*
26.63 dB



Levin *et al.*
26.55 dB



DEB-BM3D
26.82 dB



IDD-BM3D
26.93 dB

MLP
27.21 dB

4.17 Image “157087” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
22.66 dB

Direct Deconvolution
23.71 dB

EPLL
24.98 dB

Krishnan *et al.*
25.20 dB

Levin *et al.*
25.07 dB

DEB-BM3D
25.34 dB

IDD-BM3D
25.56 dB

MLP
25.84 dB

4.18 Image “145059” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
21.89 dB

Direct Deconvolution
23.13 dB

EPLL
24.09 dB

Krishnan *et al.*
24.23 dB

Levin *et al.*
24.13 dB

DEB-BM3D
24.59 dB

IDD-BM3D
24.74 dB

MLP
25.02 dB

4.19 Image “112056” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
26.91 dB

Direct Deconvolution
26.41 dB

EPLL
32.81 dB

Krishnan *et al.*
32.71 dB

Levin *et al.*
32.60 dB

DEB-BM3D
32.76 dB

IDD-BM3D
32.99 dB

MLP
33.11 dB

4.20 Image “8023” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
25.02 dB

Direct Deconvolution
25.76 dB

EPLL
28.77 dB

Krishnan *et al.*
28.96 dB

Levin *et al.*
28.94 dB

DEB-BM3D
29.35 dB

IDD-BM3D
29.41 dB

MLP
29.66 dB

4.21 Image “135069” in scenario (a): small Gaussian blur with strong noise

Ground Truth

Corrupted
27.24 dB

Direct Deconvolution
26.62 dB

EPLL
36.07 dB

Krishnan *et al.*
34.83 dB

Levin *et al.*
34.64 dB

DEB-BM3D
35.66 dB

IDD-BM3D
36.27 dB

MLP
36.75 dB

5 Scenario (b)

5.1 Image “119082” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
21.80 dB

Direct Deconvolution
24.38 dB

EPLL
26.02 dB

Krishnan *et al.*
25.97 dB

Levin *et al.*
25.71 dB

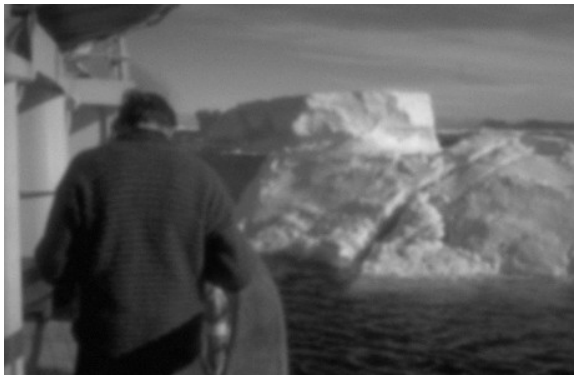
DEB-BM3D
26.12 dB

IDD-BM3D
26.74 dB

MLP
27.01 dB

5.2 Image “188005” in scenario (b): small Gaussian blur with weak noise

Ground Truth



Corrupted
28.07 dB

Direct Deconvolution
27.14 dB

EPLL
30.26 dB

Krishnan *et al.*
30.33 dB

Levin *et al.*
30.35 dB

DEB-BM3D
30.46 dB

IDD-BM3D
30.65 dB

MLP
30.65 dB

5.3 Image “123074” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
28.28 dB

Direct Deconvolution
27.57 dB

EPLL
31.19 dB

Krishnan *et al.*
31.11 dB

Levin *et al.*
31.16 dB

DEB-BM3D
31.16 dB

IDD-BM3D
31.31 dB

MLP
31.35 dB

5.4 Image “65010” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
24.31 dB

Direct Deconvolution
25.11 dB

EPLL
26.44 dB

Krishnan *et al.*
26.52 dB

Levin *et al.*
26.48 dB

DEB-BM3D
26.59 dB

IDD-BM3D
26.68 dB

MLP
26.86 dB

5.5 Image “166081” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
26.11 dB

Direct Deconvolution
26.04 dB

EPLL
28.13 dB

Krishnan *et al.*
28.16 dB

Levin *et al.*
28.12 dB

DEB-BM3D
28.23 dB

IDD-BM3D
28.40 dB

MLP
28.58 dB

5.6 Image “310007” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
26.33 dB

Direct Deconvolution
26.29 dB

EPLL
28.44 dB

Krishnan *et al.*
28.47 dB

Levin *et al.*
28.46 dB

DEB-BM3D
28.61 dB

IDD-BM3D
28.72 dB

MLP
28.81 dB

5.7 Image “65033” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
23.26 dB

Direct Deconvolution
24.61 dB

EPLL
25.48 dB

Krishnan *et al.*
25.56 dB

Levin *et al.*
25.53 dB

DEB-BM3D
25.58 dB

IDD-BM3D
25.73 dB

MLP
25.93 dB

5.8 Image “38092” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
24.57 dB

Direct Deconvolution
25.30 dB

EPLL
26.63 dB

Krishnan *et al.*
26.70 dB

Levin *et al.*
26.69 dB

DEB-BM3D
26.73 dB

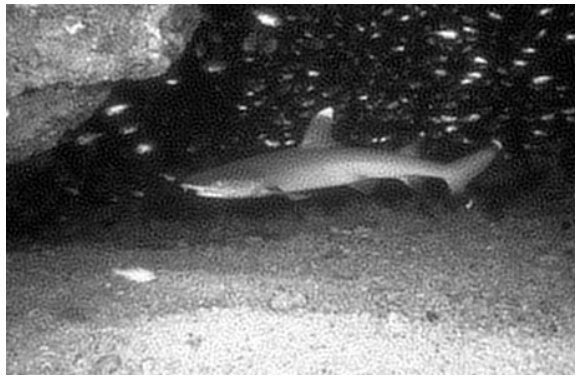
IDD-BM3D
26.82 dB

MLP
27.00 dB

5.9 Image “306052” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
25.85 dB



Direct Deconvolution
26.35 dB

EPLL
28.25 dB

Krishnan *et al.*
28.36 dB

Levin *et al.*
28.39 dB

DEB-BM3D
28.35 dB

IDD-BM3D
28.51 dB

MLP
28.61 dB

5.10 Image “41006” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
29.56 dB

Direct Deconvolution
27.59 dB

EPLL
32.11 dB

Krishnan *et al.*
32.00 dB

Levin *et al.*
31.95 dB

DEB-BM3D
32.05 dB

IDD-BM3D
32.30 dB

MLP
32.40 dB

5.11 Image “168084” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
29.61 dB

Direct Deconvolution
27.63 dB

EPLL
32.03 dB

Krishnan *et al.*
31.93 dB

Levin *et al.*
31.93 dB

DEB-BM3D
32.14 dB

IDD-BM3D
32.23 dB

MLP
32.39 dB

5.12 Image “159029” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
23.54 dB

Direct Deconvolution
25.38 dB

EPLL
26.52 dB

Krishnan *et al.*
26.53 dB

Levin *et al.*
26.53 dB

DEB-BM3D
26.62 dB

IDD-BM3D
26.73 dB

MLP
26.92 dB

5.13 Image “15062” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
23.62 dB

Direct Deconvolution
24.90 dB

EPLL
26.13 dB

Krishnan *et al.*
26.12 dB

Levin *et al.*
26.06 dB

DEB-BM3D
26.24 dB

IDD-BM3D
26.41 dB

MLP
26.74 dB

5.14 Image “183055” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
27.78 dB

Direct Deconvolution
26.69 dB

EPLL
29.65 dB

Krishnan *et al.*
29.54 dB

Levin *et al.*
29.55 dB

DEB-BM3D
29.80 dB

IDD-BM3D
29.87 dB

MLP
30.10 dB

5.15 Image “286092” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
27.71 dB

Direct Deconvolution
26.93 dB

EPLL
30.44 dB

Krishnan *et al.*
30.41 dB

Levin *et al.*
30.31 dB

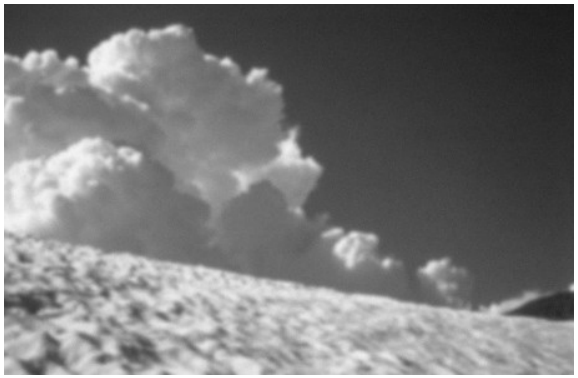
DEB-BM3D
30.35 dB

IDD-BM3D
30.68 dB

MLP
30.92 dB

5.16 Image “176039” in scenario (b): small Gaussian blur with weak noise

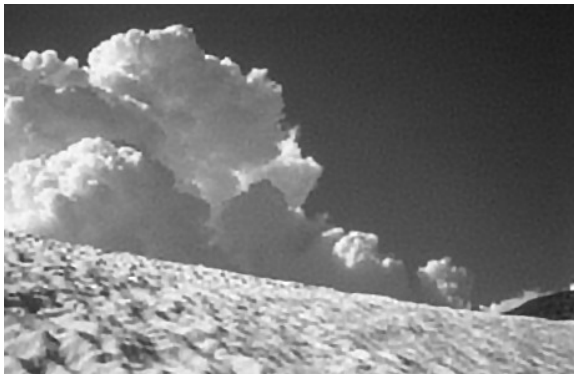
Ground Truth



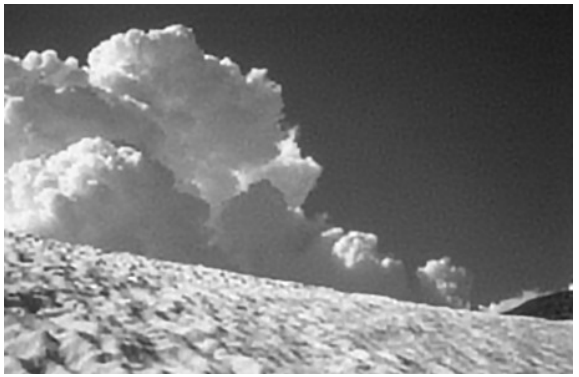
Corrupted
25.81 dB

Direct Deconvolution
26.56 dB

EPLL
29.12 dB



Krishnan *et al.*
29.10 dB



Levin *et al.*
29.02 dB

DEB-BM3D
29.21 dB

IDD-BM3D
29.40 dB

MLP
29.76 dB

5.17 Image “157087” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
24.10 dB

Direct Deconvolution
25.62 dB

EPLL
27.57 dB

Krishnan *et al.*
27.63 dB

Levin *et al.*
27.44 dB

DEB-BM3D
27.59 dB

IDD-BM3D
27.95 dB

MLP
28.26 dB

5.18 Image “145059” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
23.08 dB

Direct Deconvolution
24.99 dB

EPLL
26.62 dB

Krishnan *et al.*
26.46 dB

Levin *et al.*
26.34 dB

DEB-BM3D
26.74 dB

IDD-BM3D
27.00 dB

MLP
27.31 dB

5.19 Image “112056” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
32.98 dB

Direct Deconvolution
28.25 dB

EPLL
35.25 dB

Krishnan *et al.*
35.12 dB

Levin *et al.*
35.00 dB

DEB-BM3D
35.01 dB

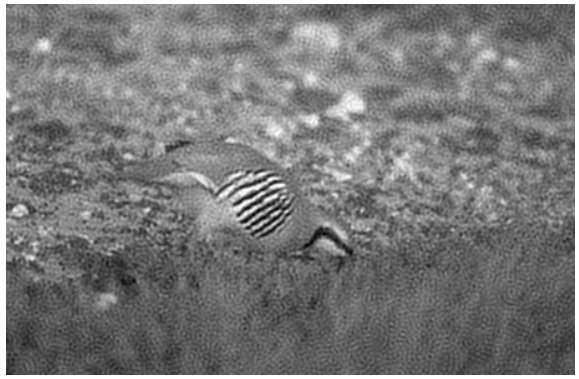
IDD-BM3D
35.26 dB

MLP
35.36 dB

5.20 Image “8023” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
27.90 dB



Direct Deconvolution
27.88 dB

EPLL
32.61 dB

Krishnan *et al.*
32.38 dB

Levin *et al.*
32.39 dB

DEB-BM3D
32.51 dB

IDD-BM3D
32.75 dB

MLP
32.91 dB

5.21 Image “135069” in scenario (b): small Gaussian blur with weak noise

Ground Truth

Corrupted
34.52 dB

Direct Deconvolution
28.47 dB

EPLL
38.75 dB

Krishnan *et al.*
37.89 dB

Levin *et al.*
37.60 dB

DEB-BM3D
38.13 dB

IDD-BM3D
38.54 dB

MLP
38.88 dB

6 Scenario (c)

6.1 Image “119082” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
18.70 dB

Direct Deconvolution
20.32 dB

EPLL
20.47 dB

Krishnan *et al.*
20.92 dB

Levin *et al.*
20.83 dB

DEB-BM3D
20.99 dB

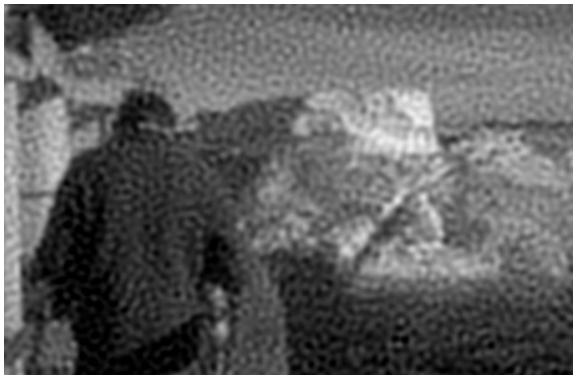
IDD-BM3D
21.34 dB

MLP
21.95 dB

6.2 Image “188005” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
23.90 dB



Direct Deconvolution
24.92 dB

EPLL
26.52 dB

Krishnan *et al.*
26.67 dB

Levin *et al.*
26.68 dB

DEB-BM3D
26.66 dB

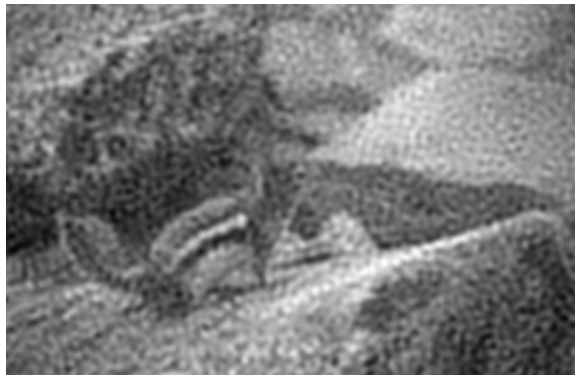
IDD-BM3D
26.76 dB

MLP
26.87 dB

6.3 Image “123074” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
23.56 dB



Direct Deconvolution
24.99 dB

EPLL
26.04 dB

Krishnan *et al.*
26.38 dB

Levin *et al.*
26.39 dB

DEB-BM3D
26.42 dB

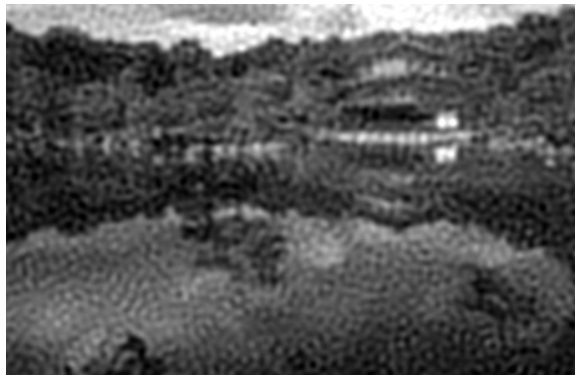
IDD-BM3D
26.42 dB

MLP
26.53 dB

6.4 Image “65010” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
21.44 dB



Direct Deconvolution
22.48 dB

EPLL
23.03 dB

Krishnan *et al.*
23.27 dB

Levin *et al.*
23.25 dB

DEB-BM3D
23.21 dB

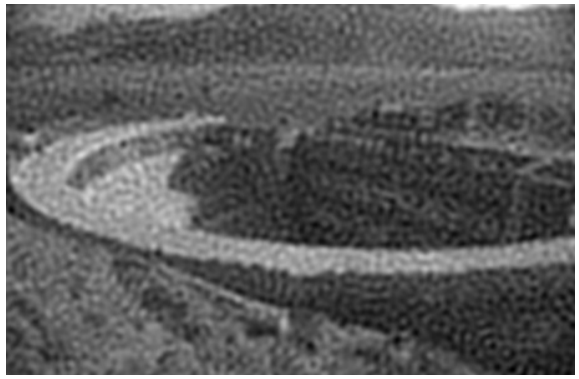
IDD-BM3D
23.29 dB

MLP
23.44 dB

6.5 Image “166081” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
22.80 dB



Direct Deconvolution
23.70 dB

EPLL
24.87 dB

Krishnan *et al.*
24.98 dB

Levin *et al.*
24.98 dB

DEB-BM3D
24.95 dB

IDD-BM3D
25.11 dB

MLP
25.26 dB

6.6 Image “310007” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
22.91 dB

Direct Deconvolution
23.85 dB

EPLL
24.98 dB

Krishnan *et al.*
25.15 dB

Levin *et al.*
25.15 dB

DEB-BM3D
25.13 dB

IDD-BM3D
25.26 dB

MLP
25.41 dB

6.7 Image “65033” in scenario (c): large Gaussian blur with strong noise

Ground Truth

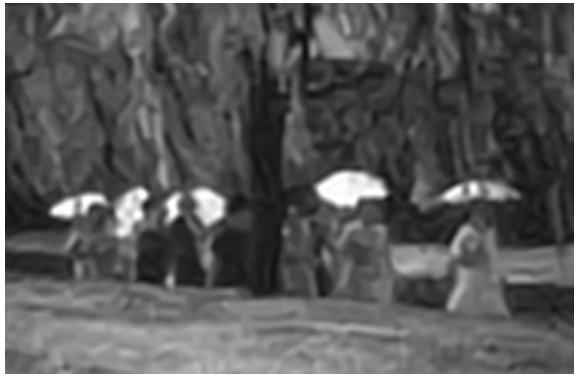
Corrupted
20.47 dB

Direct Deconvolution
21.59 dB

EPLL
21.80 dB

Krishnan *et al.*
22.10 dB

Levin *et al.*
22.09 dB



DEB-BM3D
22.11 dB

IDD-BM3D
22.15 dB

MLP
22.35 dB

6.8 Image “38092” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
21.44 dB

Direct Deconvolution
22.67 dB

EPLL
23.31 dB

Krishnan *et al.*
23.52 dB

Levin *et al.*
23.51 dB

DEB-BM3D
23.45 dB

IDD-BM3D
23.55 dB

MLP
23.73 dB

6.9 Image “306052” in scenario (c): large Gaussian blur with strong noise

Ground Truth

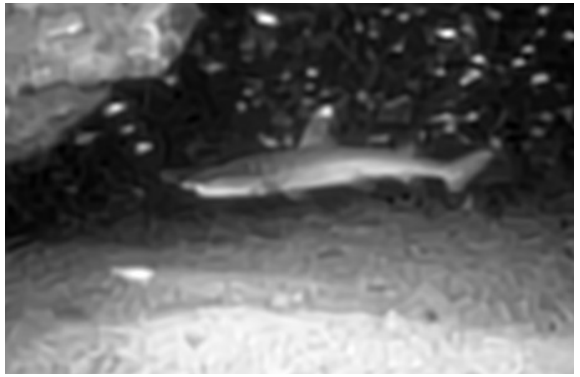
Corrupted
22.32 dB

Direct Deconvolution
23.49 dB

EPLL
24.16 dB

Krishnan *et al.*
24.45 dB

Levin *et al.*
24.49 dB



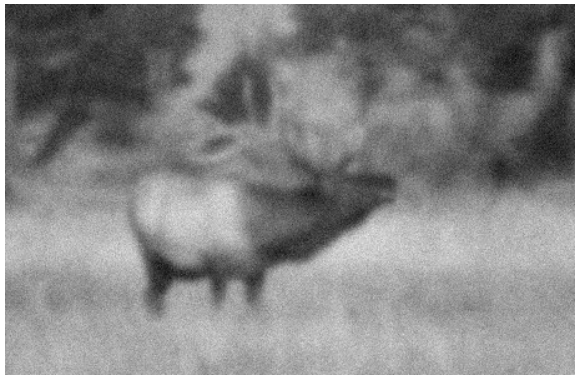
DEB-BM3D
24.47 dB

IDD-BM3D
24.50 dB

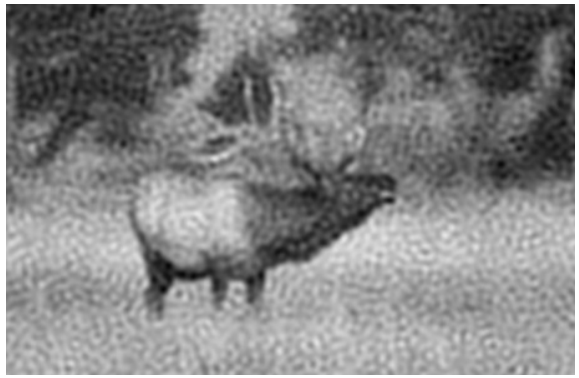
MLP
24.76 dB

6.10 Image “41006” in scenario (c): large Gaussian blur with strong noise

Ground Truth



Corrupted
24.65 dB



Direct Deconvolution
25.70 dB

EPLL
27.88 dB

Krishnan *et al.*
28.11 dB

Levin *et al.*
28.09 dB

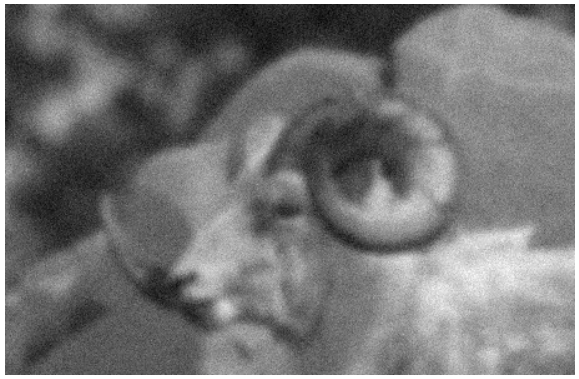
DEB-BM3D
28.00 dB

IDD-BM3D
28.14 dB

MLP
28.41 dB

6.11 Image “168084” in scenario (c): large Gaussian blur with strong noise

Ground Truth



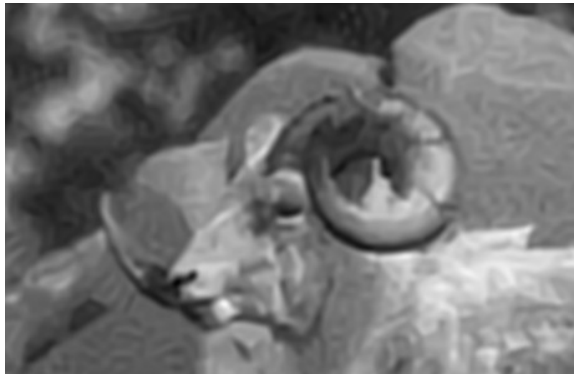
Corrupted
24.53 dB

Direct Deconvolution
25.74 dB

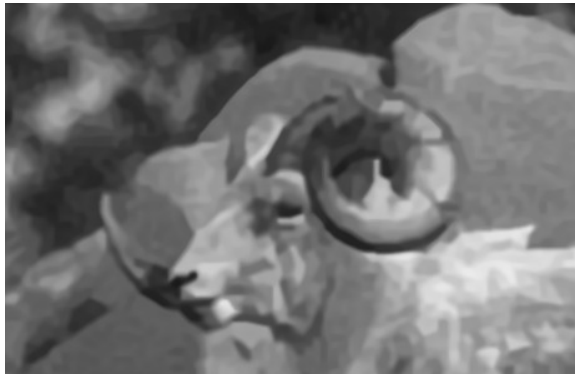
EPLL
28.04 dB

Krishnan *et al.*
28.14 dB

Levin *et al.*
28.11 dB



DEB-BM3D
28.06 dB



IDD-BM3D
28.23 dB

MLP
28.39 dB

6.12 Image “159029” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
20.12 dB

Direct Deconvolution
21.85 dB

EPLL
21.87 dB

Krishnan *et al.*
22.20 dB

Levin *et al.*
22.20 dB

DEB-BM3D
22.22 dB

IDD-BM3D
22.20 dB

MLP
22.45 dB

6.13 Image “15062” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
20.73 dB

Direct Deconvolution
21.93 dB

EPLL
22.29 dB

Krishnan *et al.*
22.55 dB

Levin *et al.*
22.54 dB

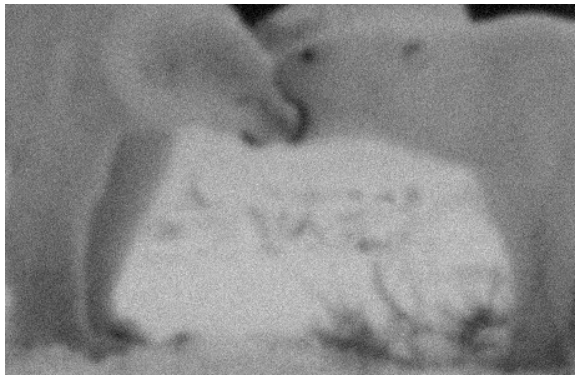
DEB-BM3D
22.58 dB

IDD-BM3D
22.66 dB

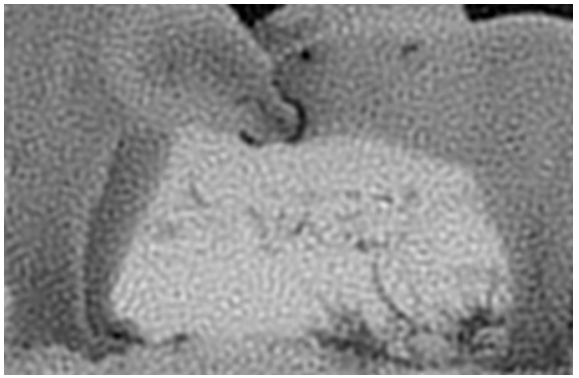
MLP
23.01 dB

6.14 Image “183055” in scenario (c): large Gaussian blur with strong noise

Ground Truth

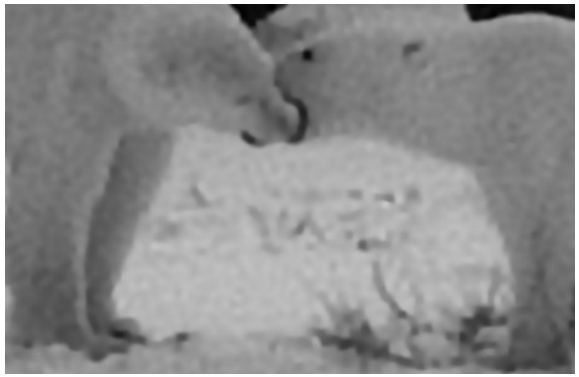


Corrupted
24.03 dB

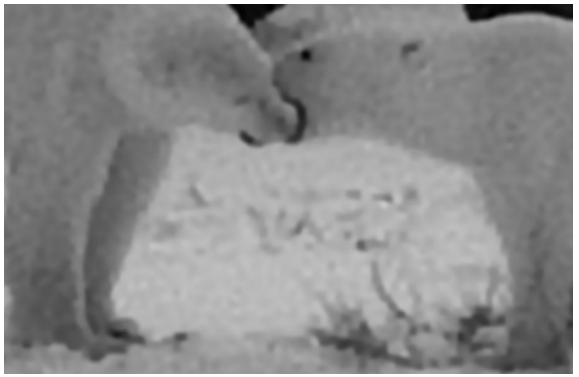


Direct Deconvolution
24.80 dB

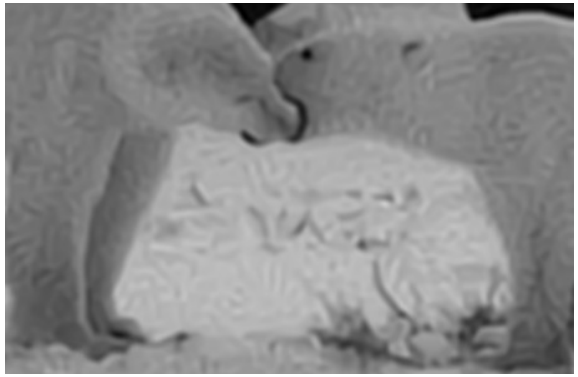
EPLL
26.57 dB



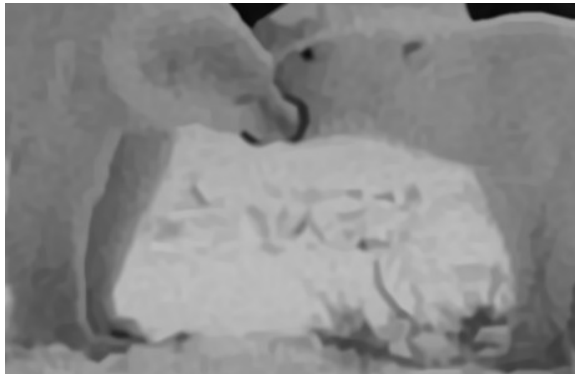
Krishnan *et al.*
26.64 dB



Levin *et al.*
26.65 dB



DEB-BM3D
26.59 dB



IDD-BM3D
26.74 dB

MLP
26.93 dB

6.15 Image “286092” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
23.62 dB

Direct Deconvolution
24.73 dB

EPLL
26.45 dB

Krishnan *et al.*
26.65 dB

Levin *et al.*
26.63 dB

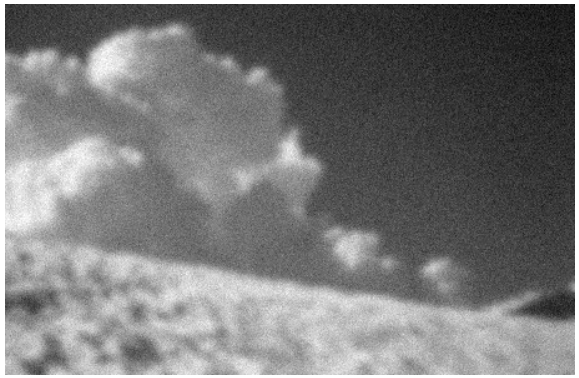
DEB-BM3D
26.49 dB

IDD-BM3D
26.84 dB

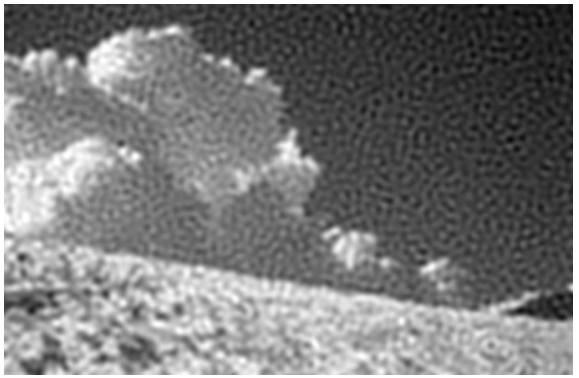
MLP
27.17 dB

6.16 Image “176039” in scenario (c): large Gaussian blur with strong noise

Ground Truth

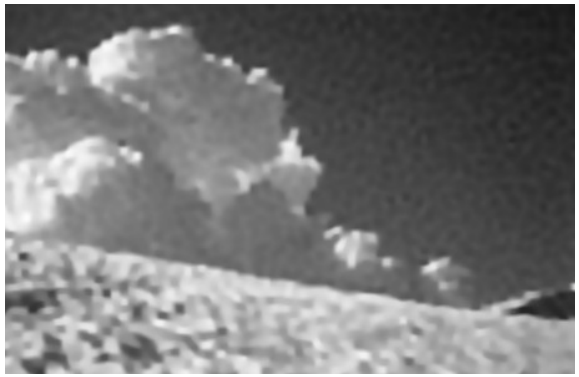


Corrupted
22.09 dB

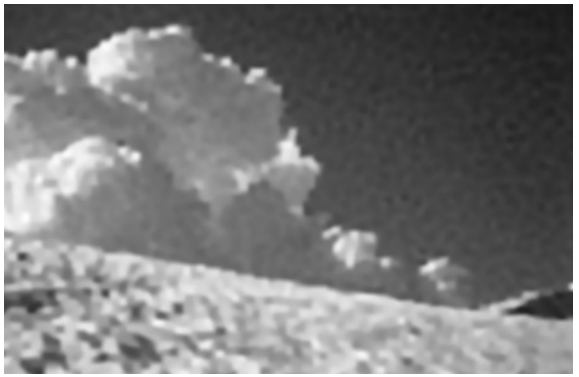


Direct Deconvolution
23.43 dB

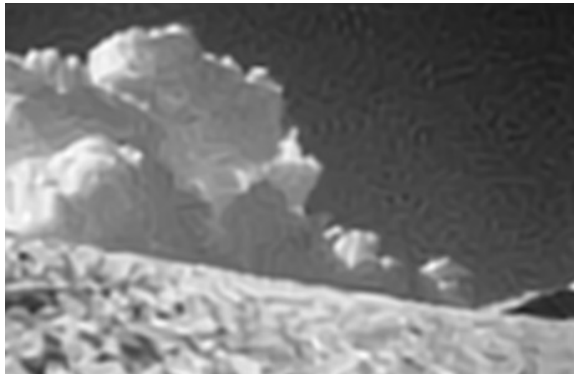
EPLL
24.18 dB



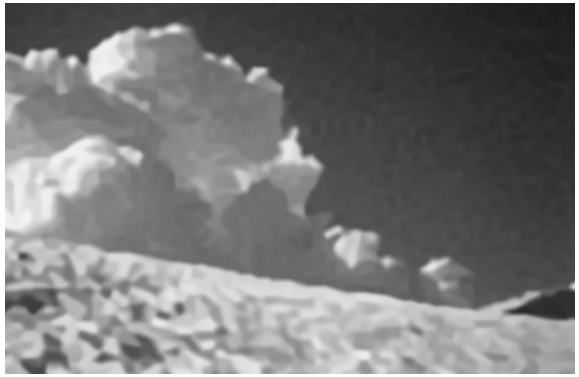
Krishnan *et al.*
24.43 dB



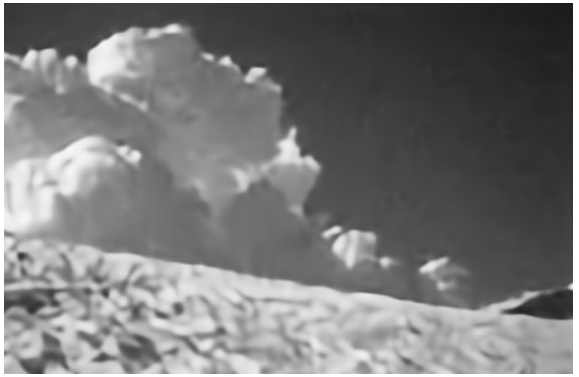
Levin *et al.*
24.44 dB



DEB-BM3D
24.40 dB



IDD-BM3D
24.51 dB



MLP
24.79 dB

6.17 Image “157087” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
20.69 dB

Direct Deconvolution
22.22 dB

EPLL
22.44 dB

Krishnan *et al.*
22.80 dB

Levin *et al.*
22.78 dB

DEB-BM3D
22.81 dB

IDD-BM3D
22.93 dB

MLP
23.35 dB

6.18 Image “145059” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
19.71 dB

Direct Deconvolution
21.45 dB

EPLL
21.52 dB

Krishnan *et al.*
21.91 dB

Levin *et al.*
21.86 dB

DEB-BM3D
21.95 dB

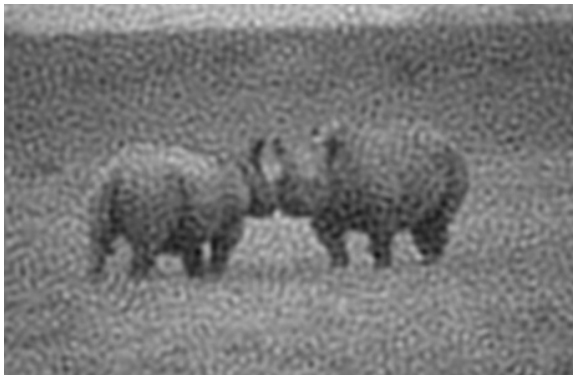
IDD-BM3D
22.08 dB

MLP
22.49 dB

6.19 Image “112056” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
26.22 dB



Direct Deconvolution
27.01 dB

EPLL
31.48 dB

Krishnan *et al.*
31.41 dB

Levin *et al.*
31.41 dB

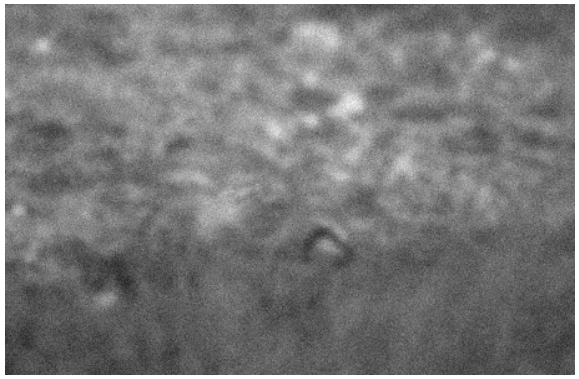
DEB-BM3D
31.08 dB

IDD-BM3D
31.61 dB

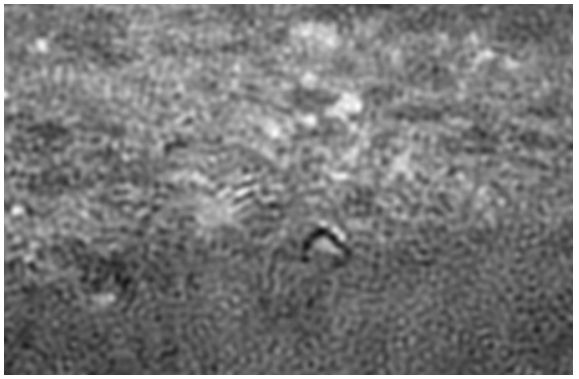
MLP
31.71 dB

6.20 Image “8023” in scenario (c): large Gaussian blur with strong noise

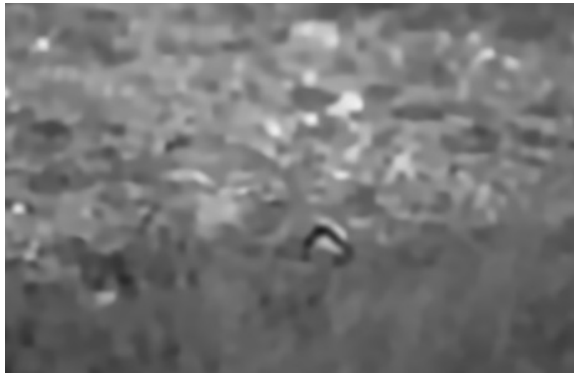
Ground Truth



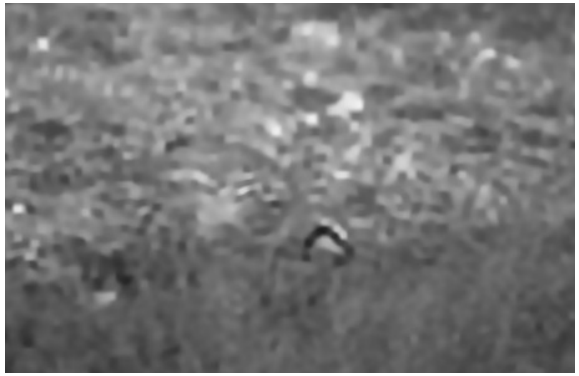
Corrupted
23.15 dB



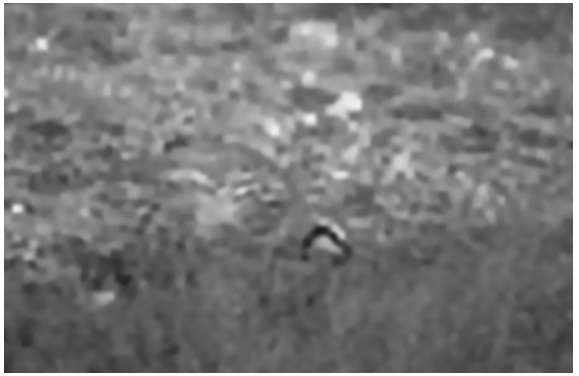
Direct Deconvolution
24.53 dB



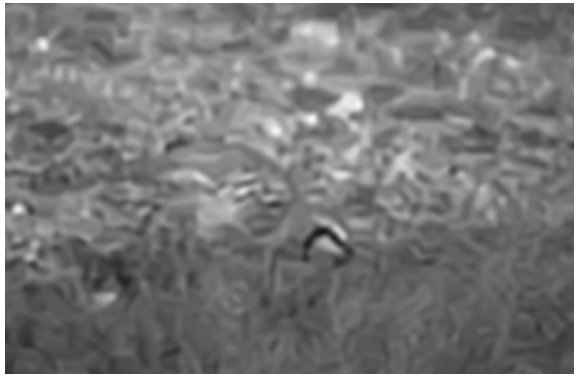
EPLL
25.15 dB



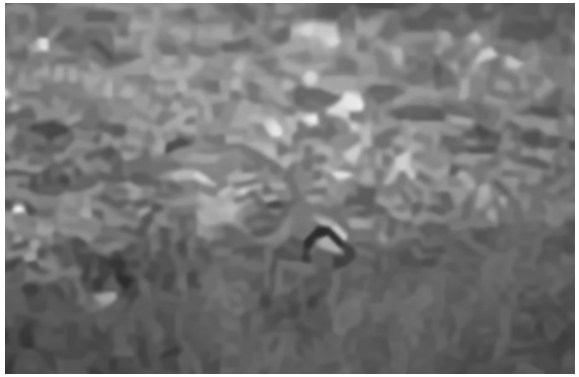
Krishnan *et al.*
25.60 dB



Levin *et al.*
25.60 dB



DEB-BM3D
25.63 dB



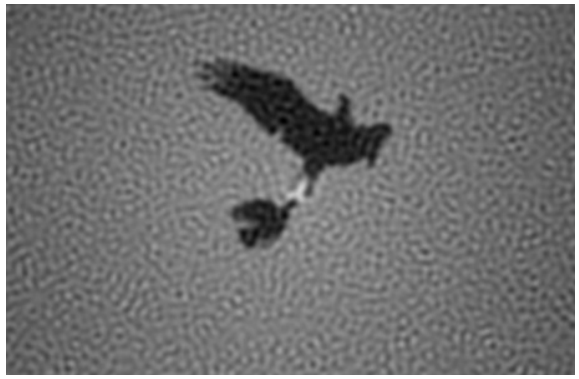
IDD-BM3D
25.51 dB

MLP
25.87 dB

6.21 Image “135069” in scenario (c): large Gaussian blur with strong noise

Ground Truth

Corrupted
26.73 dB



Direct Deconvolution
27.35 dB

EPLL
33.99 dB

Krishnan *et al.*
33.07 dB

Levin *et al.*
33.17 dB

DEB-BM3D
32.57 dB

IDD-BM3D
34.05 dB

MLP
34.44 dB

7 Scenario (d)

7.1 Image “119082” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
16.80 dB

Direct Deconvolution
21.28 dB

EPLL
21.78 dB

Krishnan *et al.*
22.80 dB

Levin *et al.*
22.29 dB

DEB-BM3D
22.92 dB

IDD-BM3D
23.78 dB

MLP
23.47 dB

7.2 Image “188005” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
23.74 dB

Direct Deconvolution
23.75 dB

EPLL
26.62 dB

Krishnan *et al.*
26.94 dB

Levin *et al.*
26.92 dB

DEB-BM3D
26.87 dB

IDD-BM3D
27.02 dB

MLP
27.03 dB

7.3 Image “123074” in scenario (d): large square blur with weak noise

Ground Truth

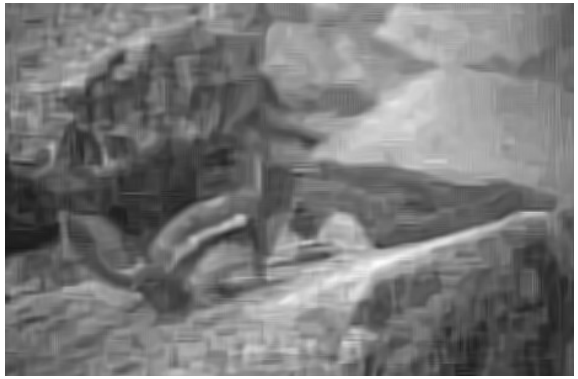
Corrupted
22.72 dB

Direct Deconvolution
23.48 dB

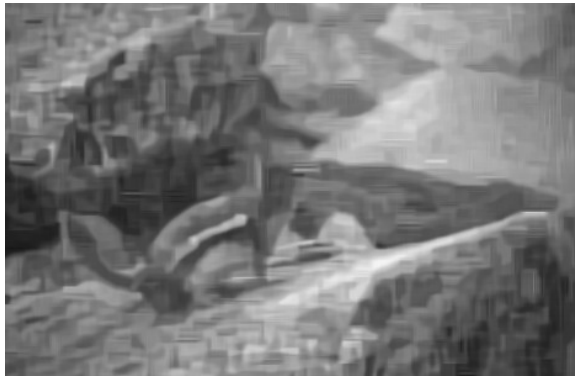
EPLL
25.61 dB

Krishnan *et al.*
26.02 dB

Levin *et al.*
25.99 dB



DEB-BM3D
26.04 dB



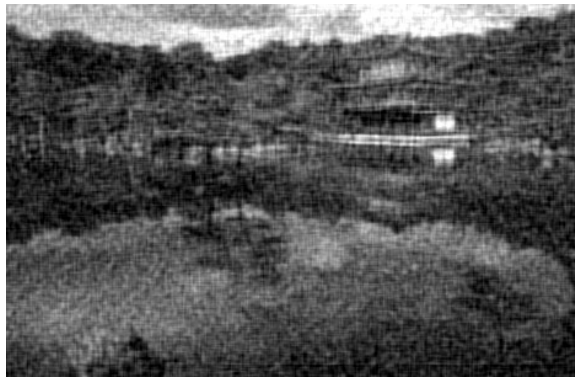
IDD-BM3D
26.13 dB

MLP
26.19 dB

7.4 Image “65010” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
20.58 dB



Direct Deconvolution
22.02 dB

EPLL
23.37 dB

Krishnan *et al.*
23.78 dB

Levin *et al.*
23.63 dB

DEB-BM3D
23.62 dB

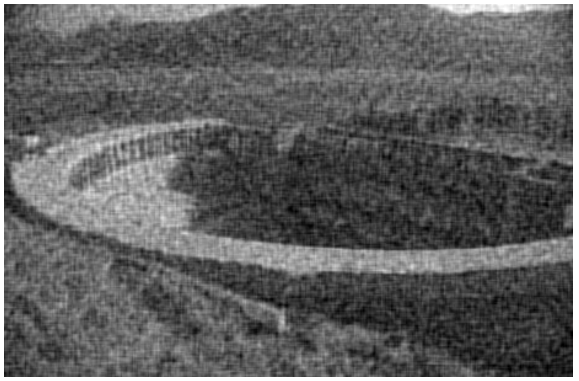
IDD-BM3D
23.80 dB

MLP
23.88 dB

7.5 Image “166081” in scenario (d): large square blur with weak noise

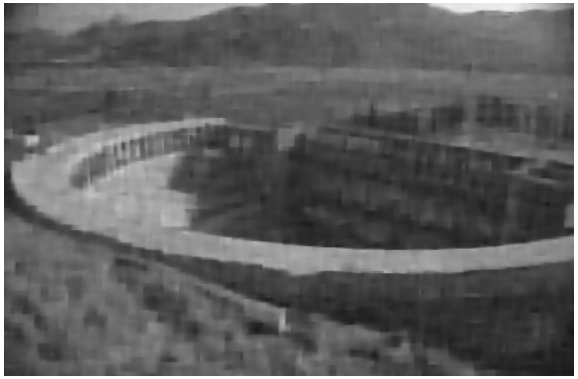
Ground Truth

Corrupted
22.48 dB



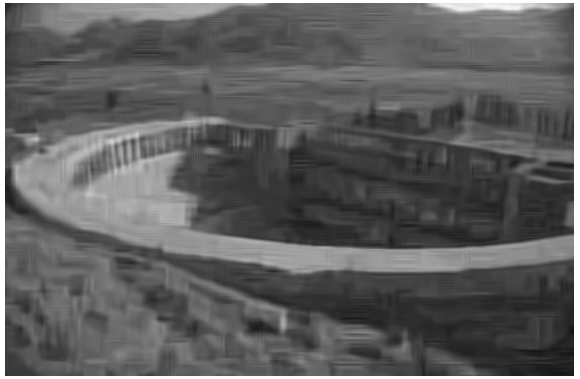
Direct Deconvolution
22.94 dB

EPLL
25.08 dB

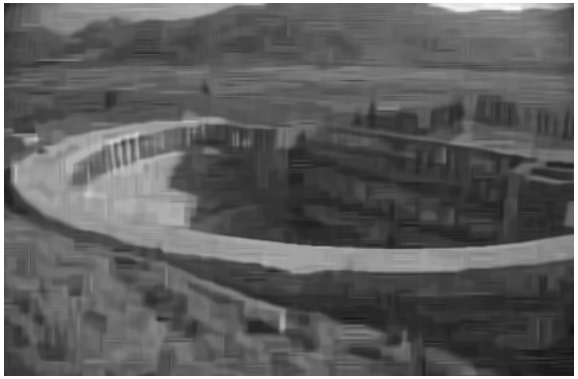


Krishnan *et al.*
25.35 dB

Levin *et al.*
25.28 dB



DEB-BM3D
25.23 dB



IDD-BM3D
25.40 dB

MLP
25.49 dB

7.6 Image “310007” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
22.57 dB

Direct Deconvolution
23.13 dB

EPLL
25.27 dB

Krishnan *et al.*
25.63 dB

Levin *et al.*
25.54 dB

DEB-BM3D
25.72 dB

IDD-BM3D
25.89 dB

MLP
26.00 dB

7.7 Image “65033” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
19.46 dB

Direct Deconvolution
21.32 dB

EPLL
21.93 dB

Krishnan *et al.*
22.37 dB

Levin *et al.*
22.26 dB

DEB-BM3D
22.30 dB

IDD-BM3D
22.48 dB

MLP
22.61 dB

7.8 Image “38092” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
20.14 dB

Direct Deconvolution
22.05 dB

EPLL
23.35 dB

Krishnan *et al.*
23.74 dB

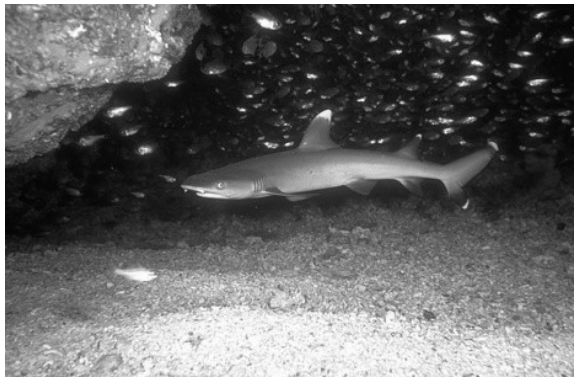
Levin *et al.*
23.66 dB

DEB-BM3D
23.51 dB

IDD-BM3D
23.74 dB

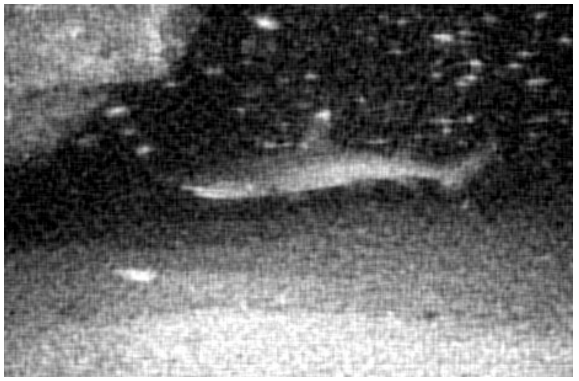
MLP
23.88 dB

7.9 Image “306052” in scenario (d): large square blur with weak noise



Ground Truth

Corrupted
21.61 dB



Direct Deconvolution
22.51 dB

EPLL
24.17 dB

Krishnan *et al.*
24.60 dB

Levin *et al.*
24.56 dB

DEB-BM3D
24.42 dB

IDD-BM3D
24.72 dB

MLP
24.87 dB

7.10 Image “41006” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
24.59 dB

Direct Deconvolution
24.11 dB

EPLL
28.02 dB

Krishnan *et al.*
28.31 dB

Levin *et al.*
28.29 dB

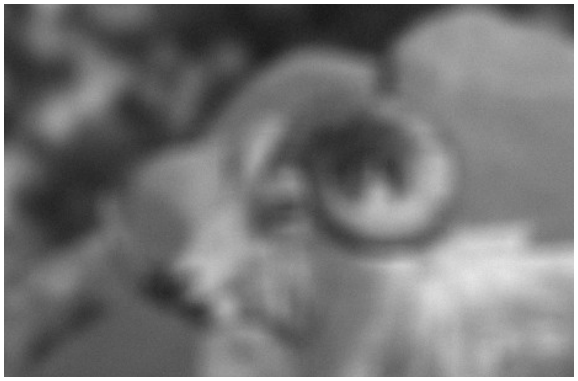
DEB-BM3D
28.01 dB

IDD-BM3D
28.28 dB

MLP
28.45 dB

7.11 Image “168084” in scenario (d): large square blur with weak noise

Ground Truth



Corrupted
23.98 dB

Direct Deconvolution
23.99 dB

EPLL
27.61 dB

Krishnan *et al.*
27.80 dB

Levin *et al.*
27.83 dB

DEB-BM3D
27.62 dB

IDD-BM3D
27.82 dB

MLP
28.01 dB

7.12 Image “159029” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
18.21 dB

Direct Deconvolution
21.43 dB

EPLL
21.79 dB

Krishnan *et al.*
22.29 dB

Levin *et al.*
22.15 dB

DEB-BM3D
22.30 dB

IDD-BM3D
22.45 dB

MLP
22.65 dB

7.13 Image “15062” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
19.55 dB

Direct Deconvolution
21.58 dB

EPLL
22.52 dB

Krishnan *et al.*
22.94 dB

Levin *et al.*
22.83 dB

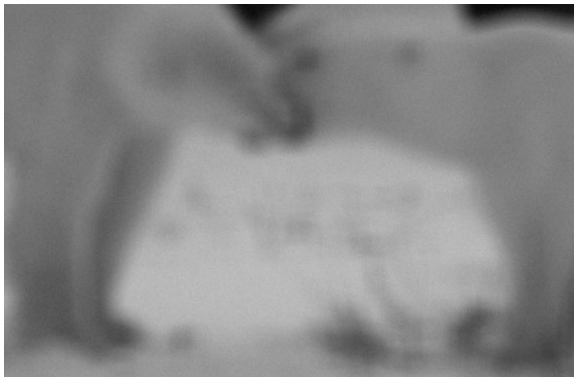
DEB-BM3D
22.93 dB

IDD-BM3D
23.15 dB

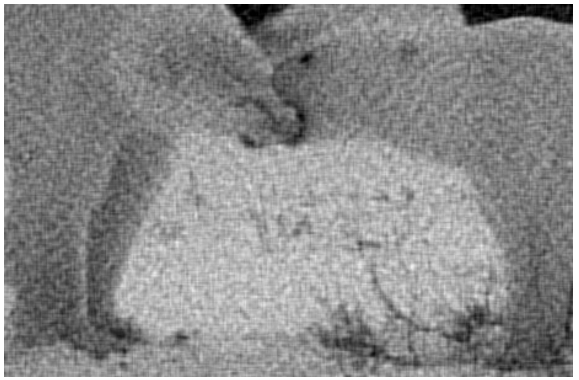
MLP
23.38 dB

7.14 Image “183055” in scenario (d): large square blur with weak noise

Ground Truth



Corrupted
24.48 dB



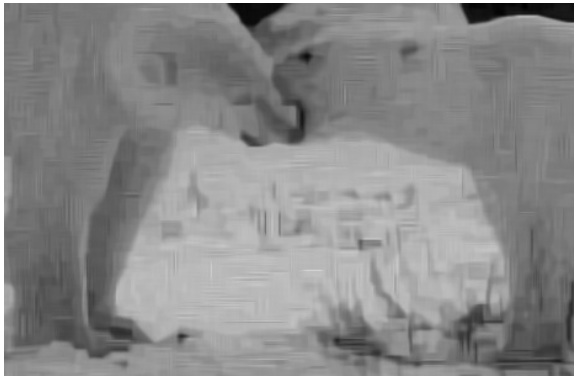
Direct Deconvolution
23.49 dB

EPLL
26.59 dB

Krishnan *et al.*
26.75 dB

Levin *et al.*
26.76 dB

DEB-BM3D
26.61 dB



IDD-BM3D
26.73 dB

MLP
26.97 dB

7.15 Image “286092” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
23.30 dB

Direct Deconvolution
23.57 dB

EPLL
26.83 dB

Krishnan *et al.*
27.21 dB

Levin *et al.*
27.15 dB

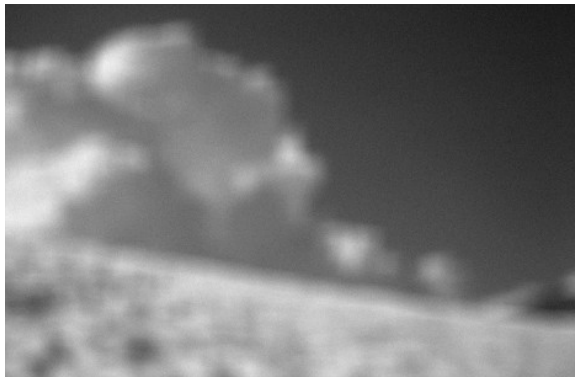
DEB-BM3D
26.81 dB

IDD-BM3D
27.26 dB

MLP
27.53 dB

7.16 Image “176039” in scenario (d): large square blur with weak noise

Ground Truth

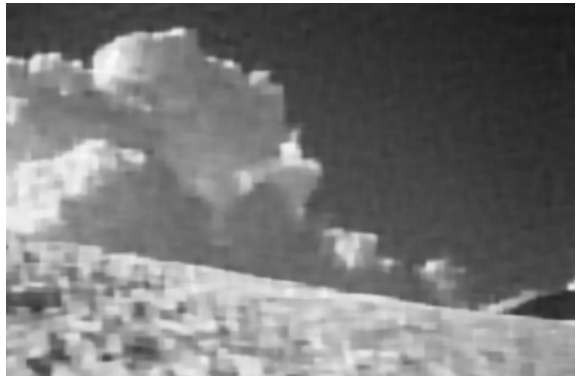


Corrupted
21.11 dB

Direct Deconvolution
22.48 dB

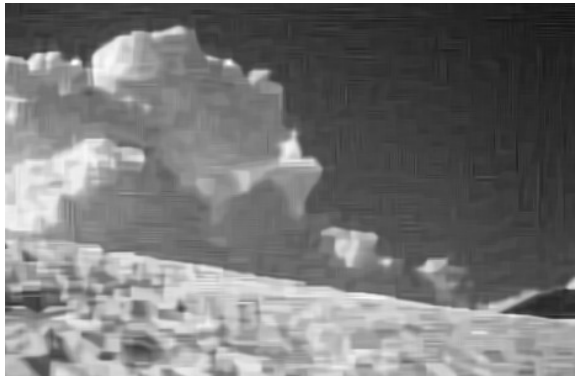
EPLL
24.06 dB

Krishnan *et al.*
24.49 dB



Levin *et al.*
24.39 dB

DEB-BM3D
24.40 dB



IDD-BM3D
24.63 dB

MLP
24.93 dB

7.17 Image “157087” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
19.13 dB

Direct Deconvolution
21.67 dB

EPLL
22.48 dB

Krishnan *et al.*
23.02 dB

Levin *et al.*
22.88 dB

DEB-BM3D
22.96 dB

IDD-BM3D
23.27 dB

MLP
23.60 dB

7.18 Image “145059” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
17.89 dB

Direct Deconvolution
20.97 dB

EPLL
21.35 dB

Krishnan *et al.*
21.87 dB

Levin *et al.*
21.74 dB

DEB-BM3D
22.02 dB

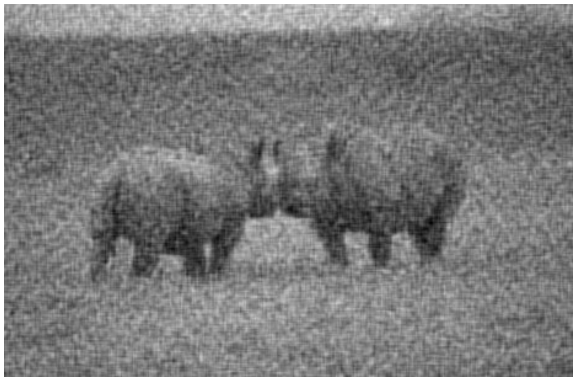
IDD-BM3D
22.38 dB

MLP
22.75 dB

7.19 Image “112056” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
27.92 dB



Direct Deconvolution
24.78 dB

EPLL
31.43 dB

Krishnan *et al.*
31.35 dB

Levin *et al.*
31.55 dB

DEB-BM3D
30.79 dB

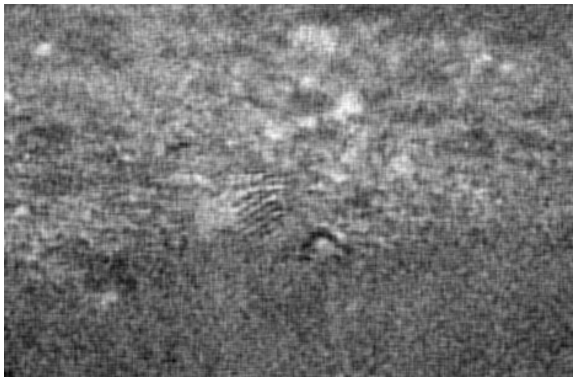
IDD-BM3D
30.98 dB

MLP
31.42 dB

7.20 Image “8023” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
22.61 dB

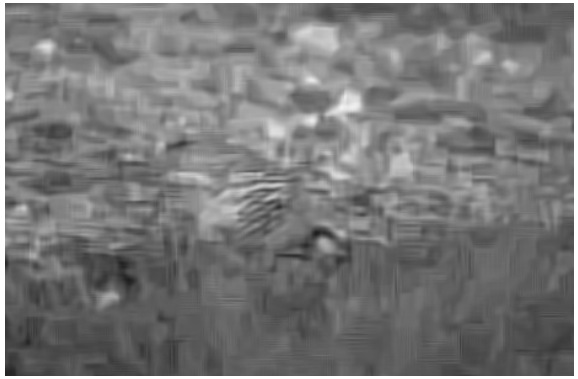


Direct Deconvolution
23.26 dB

EPLL
24.93 dB

Krishnan *et al.*
25.42 dB

Levin *et al.*
25.30 dB



DEB-BM3D
25.46 dB

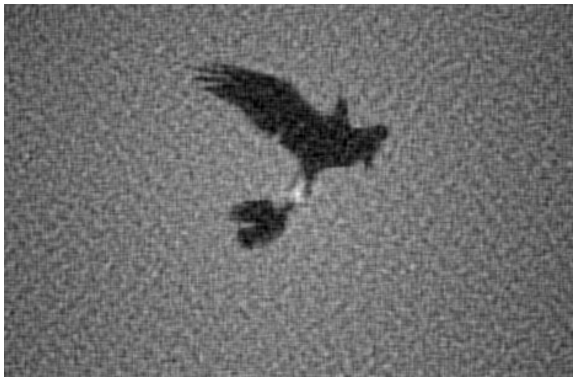
IDD-BM3D
25.41 dB

MLP
26.00 dB

7.21 Image “135069” in scenario (d): large square blur with weak noise

Ground Truth

Corrupted
29.92 dB



Direct Deconvolution
25.00 dB

EPLL
34.18 dB

Krishnan *et al.*
33.53 dB

Levin *et al.*
33.95 dB

DEB-BM3D
33.24 dB

IDD-BM3D
33.43 dB

MLP
35.10 dB

8 Scenario (e)

8.1 Image “119082” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
16.25 dB

Direct Deconvolution
23.42 dB

EPLL
28.49 dB

Krishnan *et al.*
27.22 dB

Levin *et al.*
27.14 dB

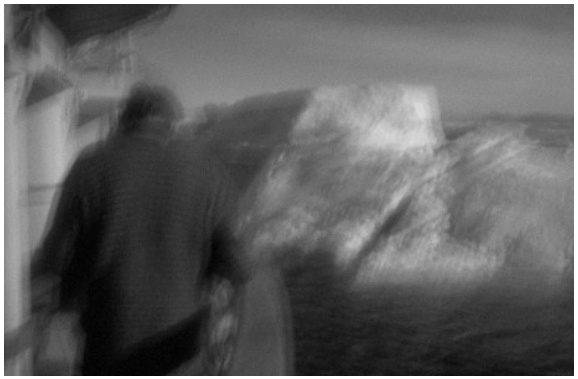
DEB-BM3D
28.69 dB

IDD-BM3D
29.72 dB

MLP
29.03 dB

8.2 Image “188005” in scenario (e): motion blur with weak noise

Ground Truth



Corrupted
23.53 dB

Direct Deconvolution
24.03 dB

EPLL
30.64 dB

Krishnan *et al.*
30.35 dB

Levin *et al.*
30.54 dB

DEB-BM3D
30.79 dB

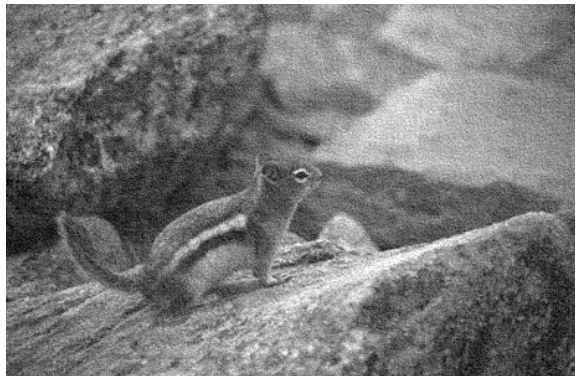
IDD-BM3D
31.25 dB

MLP
31.06 dB

8.3 Image “123074” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
22.51 dB



Direct Deconvolution
24.09 dB

EPLL
31.62 dB

Krishnan *et al.*
30.94 dB

Levin *et al.*
31.23 dB

DEB-BM3D
31.20 dB

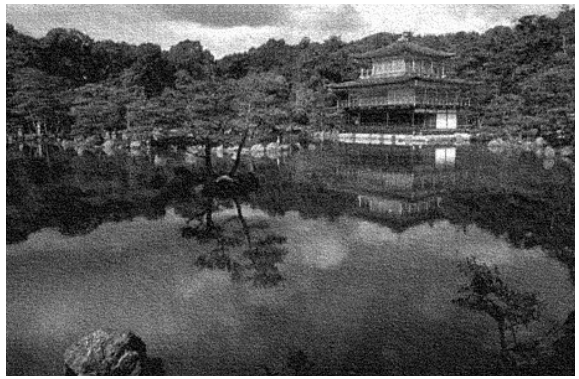
IDD-BM3D
31.51 dB

MLP
31.66 dB

8.4 Image “65010” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
19.94 dB



Direct Deconvolution
23.67 dB

EPLL
28.17 dB

Krishnan *et al.*
27.72 dB

Levin *et al.*
27.72 dB

DEB-BM3D
27.92 dB

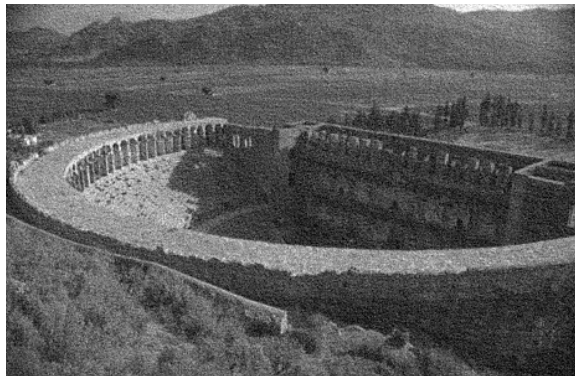
IDD-BM3D
28.35 dB

MLP
28.59 dB

8.5 Image “166081” in scenario (e): motion blur with weak noise

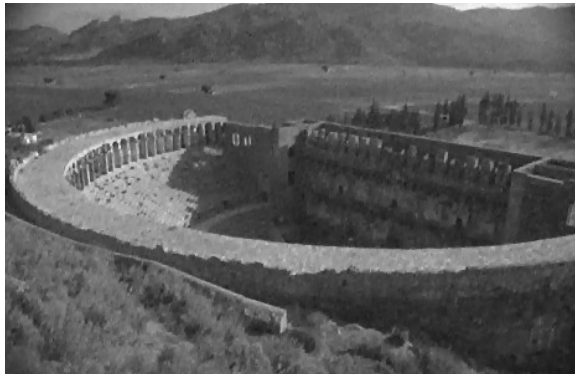
Ground Truth

Corrupted
21.79 dB

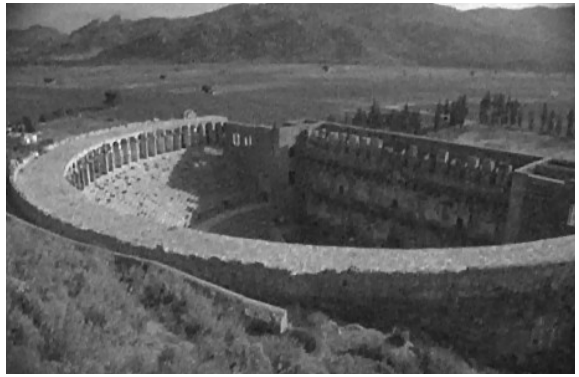


Direct Deconvolution
23.86 dB

EPLL
29.27 dB



Krishnan *et al.*
28.93 dB



Levin *et al.*
29.00 dB

DEB-BM3D
29.06 dB

IDD-BM3D
29.63 dB

MLP
29.55 dB

8.6 Image “310007” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
22.10 dB

Direct Deconvolution
23.87 dB

EPLL
29.28 dB

Krishnan *et al.*
28.77 dB

Levin *et al.*
28.90 dB

DEB-BM3D
29.34 dB

IDD-BM3D
29.73 dB

MLP
29.82 dB

8.7 Image “65033” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
19.18 dB

Direct Deconvolution
23.73 dB

EPLL
27.47 dB

Krishnan *et al.*
27.14 dB

Levin *et al.*
27.26 dB

DEB-BM3D
27.04 dB

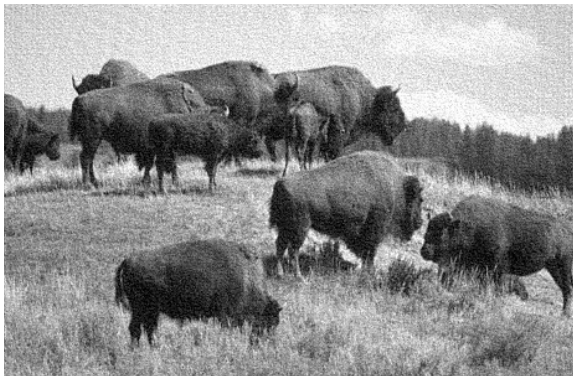
IDD-BM3D
27.61 dB

MLP
27.84 dB

8.8 Image “38092” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
19.62 dB



Direct Deconvolution
23.84 dB

EPLL
28.39 dB

Krishnan *et al.*
28.10 dB

Levin *et al.*
28.25 dB

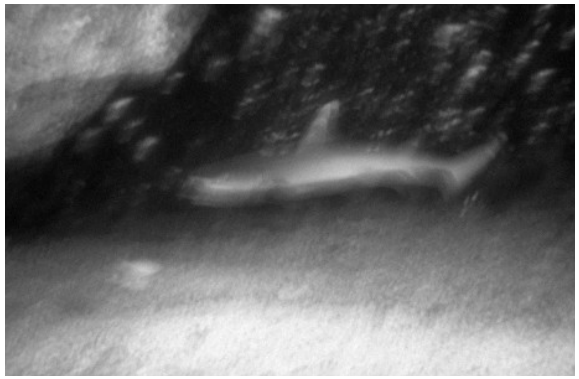
DEB-BM3D
28.07 dB

IDD-BM3D
28.40 dB

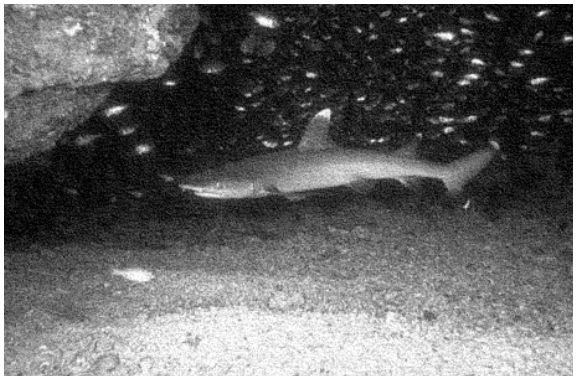
MLP
28.73 dB

8.9 Image “306052” in scenario (e): motion blur with weak noise

Ground Truth



Corrupted
21.11 dB



Direct Deconvolution
23.89 dB

EPLL
29.07 dB

Krishnan *et al.*
28.89 dB

Levin *et al.*
29.09 dB

DEB-BM3D
28.66 dB

IDD-BM3D
29.27 dB

MLP
29.40 dB

8.10 Image “41006” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
24.34 dB

Direct Deconvolution
24.12 dB

EPLL
32.91 dB

Krishnan *et al.*
32.42 dB

Levin *et al.*
32.46 dB

DEB-BM3D
32.61 dB

IDD-BM3D
33.12 dB

MLP
33.00 dB

8.11 Image “168084” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
23.66 dB

Direct Deconvolution
24.10 dB

EPLL
32.57 dB

Krishnan *et al.*
31.93 dB

Levin *et al.*
32.03 dB

DEB-BM3D
32.30 dB

IDD-BM3D
32.79 dB

MLP
32.76 dB

8.12 Image “159029” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
18.05 dB

Direct Deconvolution
23.78 dB

EPLL
27.94 dB

Krishnan *et al.*
27.30 dB

Levin *et al.*
27.57 dB

DEB-BM3D
27.67 dB

IDD-BM3D
27.81 dB

MLP
28.31 dB

8.13 Image “15062” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
19.51 dB

Direct Deconvolution
23.83 dB

EPLL
28.82 dB

Krishnan *et al.*
28.24 dB

Levin *et al.*
28.34 dB

DEB-BM3D
28.36 dB

IDD-BM3D
28.65 dB

MLP
29.08 dB

8.14 Image “183055” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
24.04 dB

Direct Deconvolution
24.02 dB

EPLL
32.25 dB

Krishnan *et al.*
31.15 dB

Levin *et al.*
31.06 dB

DEB-BM3D
31.86 dB

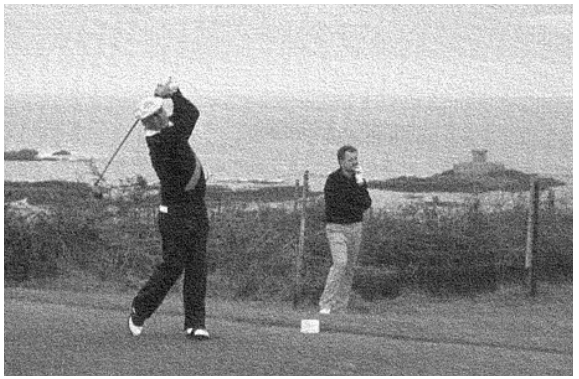
IDD-BM3D
32.43 dB

MLP
32.48 dB

8.15 Image “286092” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
22.84 dB



Direct Deconvolution
24.01 dB

EPLL
31.56 dB

Krishnan *et al.*
31.07 dB

Levin *et al.*
31.10 dB

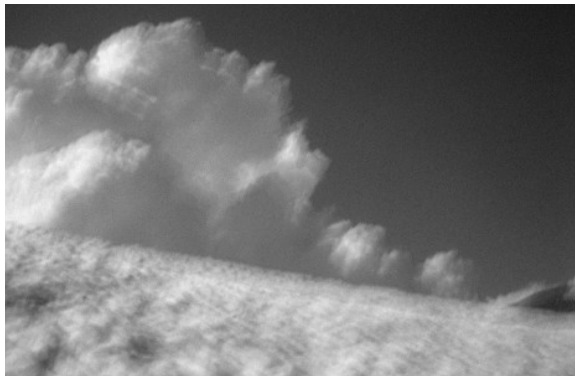
DEB-BM3D
31.15 dB

IDD-BM3D
31.70 dB

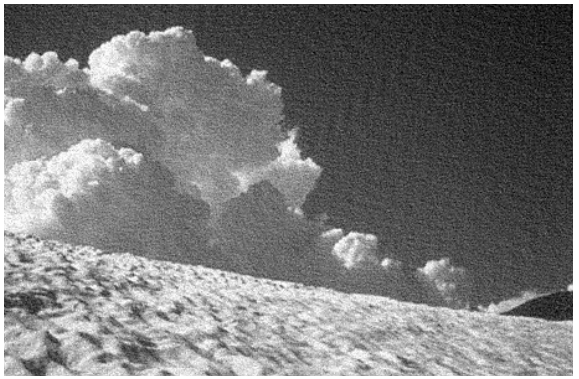
MLP
31.68 dB

8.16 Image “176039” in scenario (e): motion blur with weak noise

Ground Truth



Corrupted
20.66 dB



Direct Deconvolution
23.88 dB

EPLL
30.28 dB

Krishnan *et al.*
29.40 dB

Levin *et al.*
29.56 dB

DEB-BM3D
30.05 dB

IDD-BM3D
30.47 dB

MLP
30.77 dB

8.17 Image “157087” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
19.14 dB

Direct Deconvolution
23.82 dB

EPLL
29.42 dB

Krishnan *et al.*
28.87 dB

Levin *et al.*
28.94 dB

DEB-BM3D
28.76 dB

IDD-BM3D
29.46 dB

MLP
29.50 dB

8.18 Image “145059” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
17.74 dB

Direct Deconvolution
23.79 dB

EPLL
29.43 dB

Krishnan *et al.*
28.21 dB

Levin *et al.*
28.34 dB

DEB-BM3D
29.23 dB

IDD-BM3D
29.61 dB

MLP
29.69 dB

8.19 Image “112056” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
27.54 dB

Direct Deconvolution
24.17 dB

EPLL
35.14 dB

Krishnan *et al.*
34.64 dB

Levin *et al.*
34.48 dB

DEB-BM3D
34.69 dB

IDD-BM3D
35.23 dB

MLP
35.11 dB

8.20 Image “8023” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
21.79 dB

Direct Deconvolution
24.13 dB

EPLL
32.89 dB

Krishnan *et al.*
31.91 dB

Levin *et al.*
32.26 dB

DEB-BM3D
32.47 dB

IDD-BM3D
32.73 dB

MLP
32.86 dB

8.21 Image “135069” in scenario (e): motion blur with weak noise

Ground Truth

Corrupted
29.42 dB

Direct Deconvolution
24.18 dB

EPLL
40.70 dB

Krishnan *et al.*
37.78 dB

Levin *et al.*
36.94 dB

DEB-BM3D
40.42 dB

IDD-BM3D
41.24 dB

MLP
40.42 dB