Image denoising: Can plain Neural Networks compete with BM3D?

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MAX-PLANCK-GESELLSCHAFT

Denoising with a neural network

- E.g. an MLP with two hidden layers:

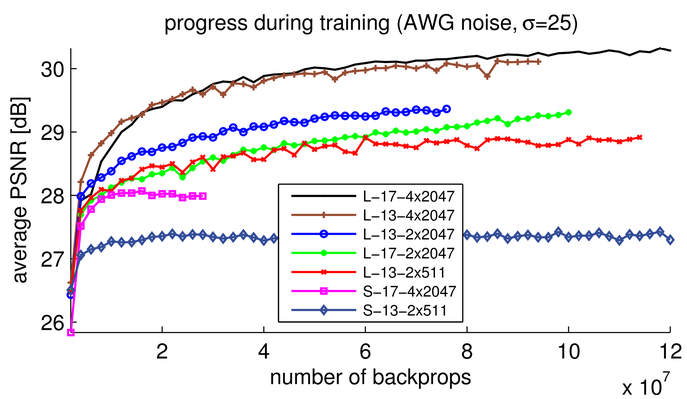
$$f(x) = b_3 + W_3 \tanh(b_2 + W_2 \tanh(b_1 + W_1 x)),$$

x is the noisy patch, $f(x)$ is the denoised patch.

- Training via stochastic gradient descent on clean/noisy patch pairs (generated on the fly).

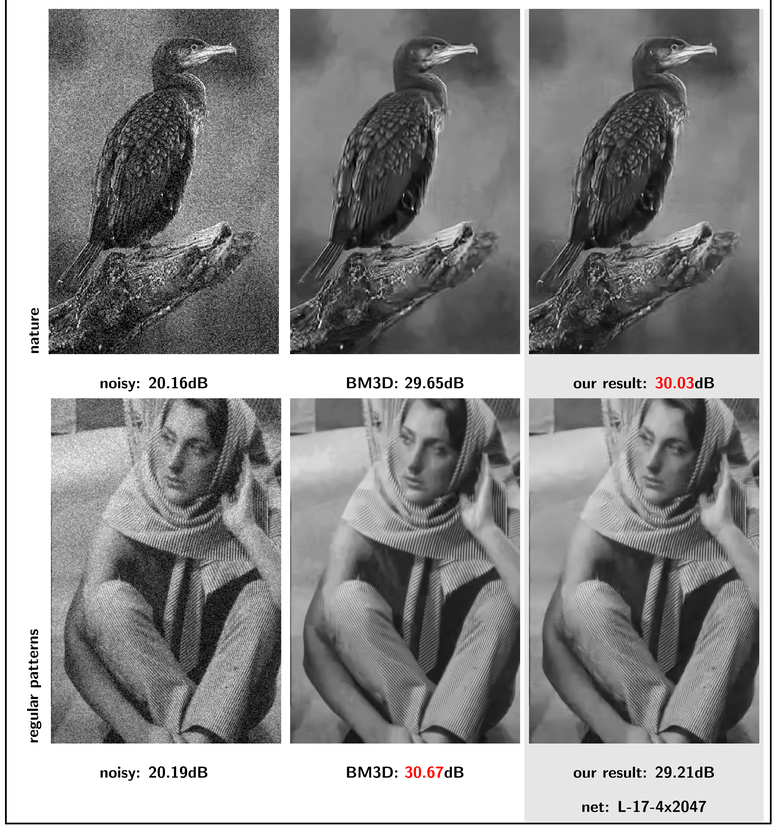
State-of-the-art results are possible with:

1. Large variability in training data (S: 200, L: 150000 images)
2. Large patch sizes (13x13, 17x17)
3. High capacity MLPs (hidden layers: 4x2047, 2x2047, 2x511)
4. Long training times (more than 10^8 backprops)

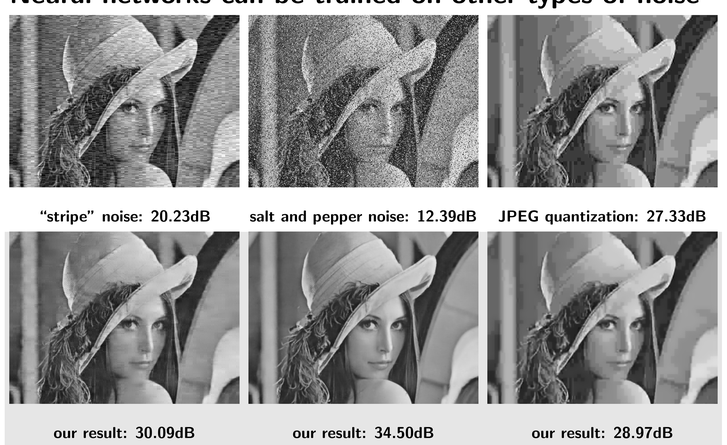


- Computationally feasible through GPUs.
- No overfitting due to abundance of data.

Results 1:



Neural networks can be trained on other types of noise

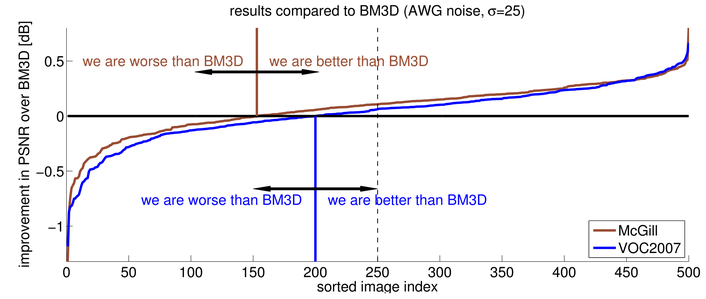


Results 2: Comparison against other algorithms.

image	GSM [3]	KSVD [1]	BM3D [2]	us
Cameraman	28.66	28.71	29.40	29.43
Peppers	29.50	29.66	30.19	30.28
Lena	31.27	31.30	32.05	32.12
Boats	29.25	29.28	29.85	29.84
Barbara	27.83	29.50	30.66	29.21

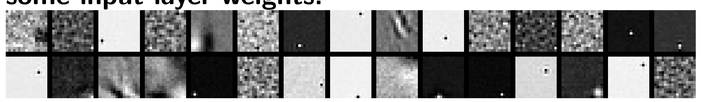
$\sigma = 25$. Red is best, blue is the runner-up.

Results 3: Performance profile.

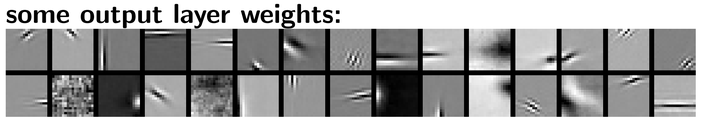


Can we understand how the MLP works?

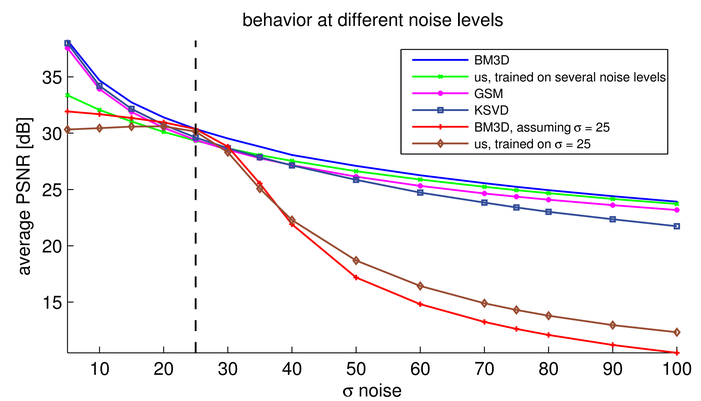
some input layer weights:



some output layer weights:



Limitations:



Average results obtained on images "Lena" and "Barbara".

References

[1] M. Aharon, M. Elad, and A. Bruckstein. K-svd: An algorithm for designing overcomplete dictionaries for sparse representation. *IEEE Transactions on Signal Processing*, 54(11):4311–4322, 2006.

[2] K. Dabov, A. Foi, V. Katkovnik, and K. Egiazarian. Image denoising by sparse 3-D transform-domain collaborative filtering. *IEEE Transactions on Image Processing*, 16(8):2080–2095, 2007.

[3] J. Portilla, V. Strela, M.J. Wainwright, and E.P. Simoncelli. Image denoising using scale mixtures of Gaussians in the wavelet domain. *IEEE Transactions on Image Processing*, 12(11):1338–1351, 2003.