

Image denoising using convolutional neural networks and the Natural Image Noise Dataset

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Promoter: Christophe De Vleeschouwer

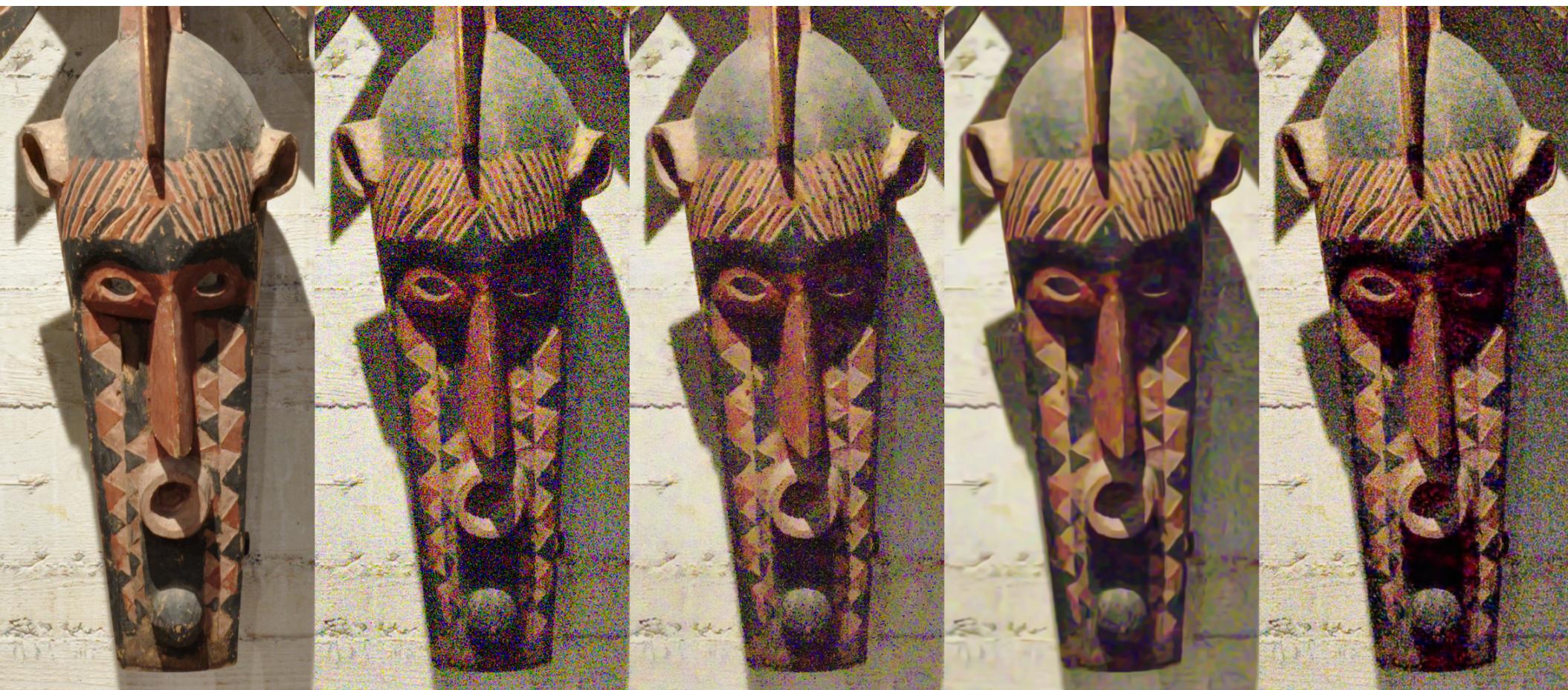


Problem: photographic image noise



Current solutions

- Commonly used: non-local means, bilateral filter, wavelet, ...
- State-of-the-art: block-matching and 3D filtering (BM3D)
- Active research: convolutional neural networks



Ground-truth
1 sec.

Noisy
1/170 sec.

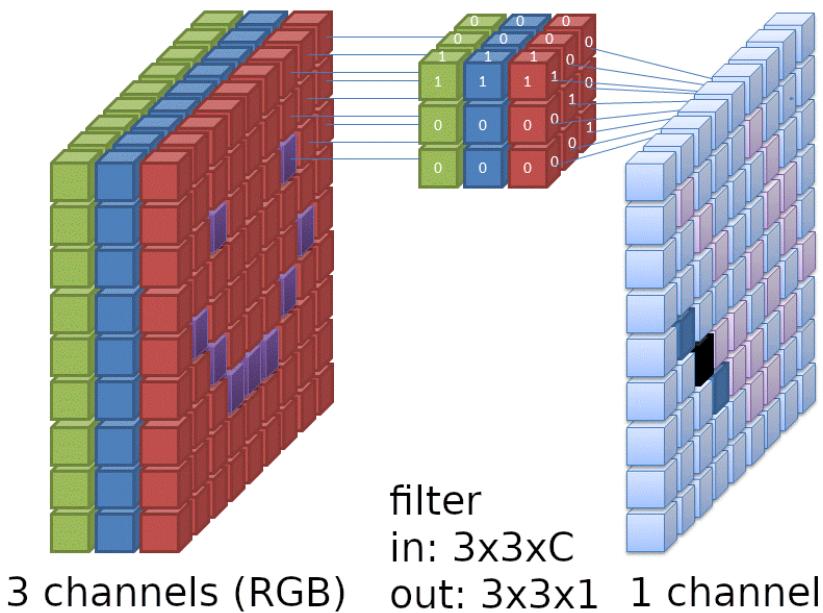
Non-local means
darktable sw implementation

BM3D
 $\sigma=99$

CNN
trained on gaussian noise

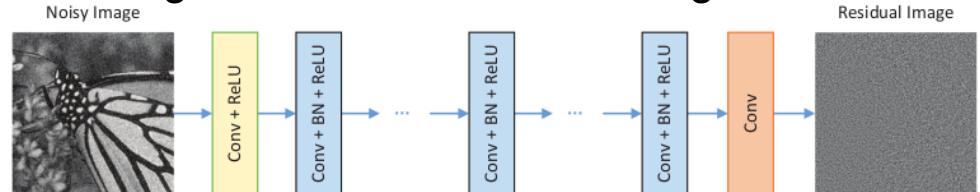
Convolutional neural networks

Main building block: convolution



Apply the same filter to every $3 \times 3 \times C_{in}$ area
Repeat the process with different filters for C_{out} channels

Different architectures made of the same building blocks in different configurations



Beyond a Gaussian Denoiser: Residual Learning of Deep CNN for Image Denoising, by Zhang et al. (2016)

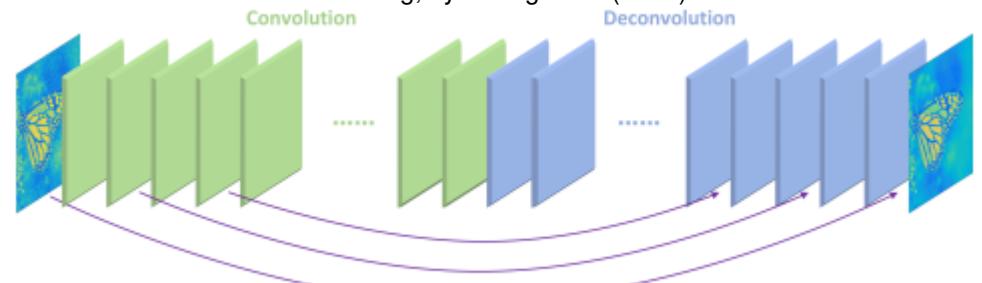
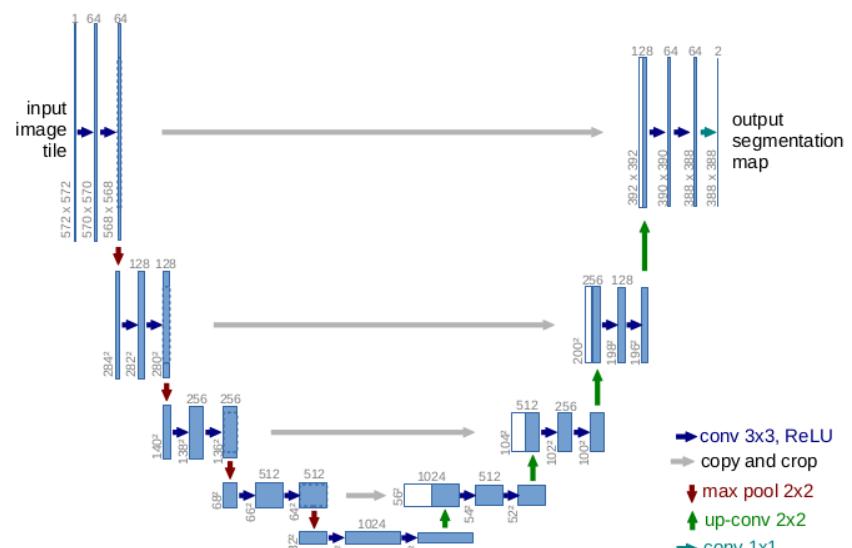
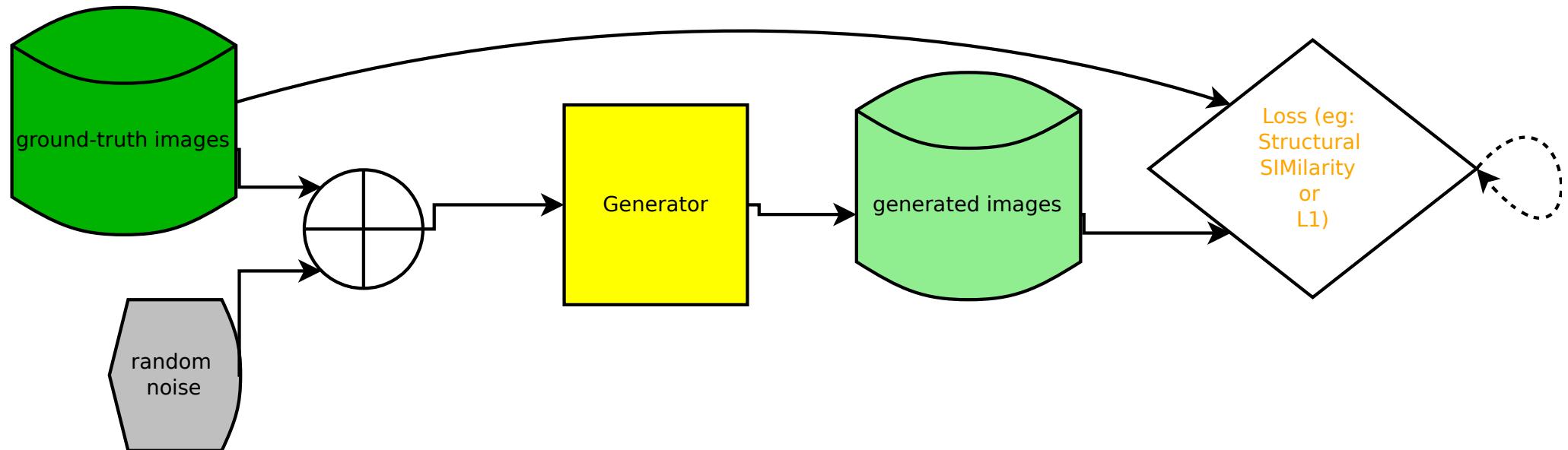


Image Restoration Using Very Deep Convolutional Encoder-Decoder Networks with Symmetric Skip Connections, by Mao et al. (2016)

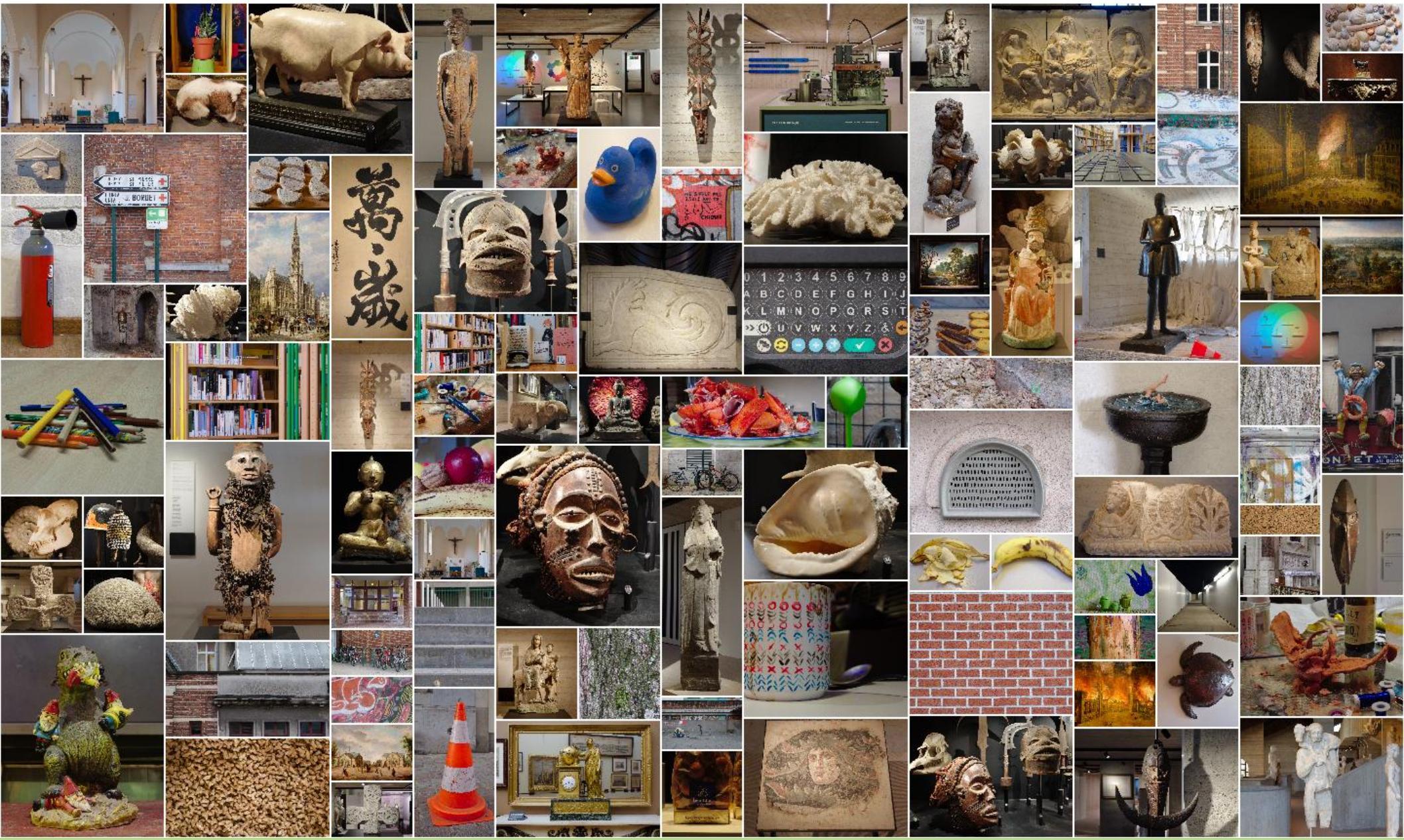


U-Net: Convolutional Networks for Biomedical Image Segmentation, by Ronneberger et al. (2015)

Convolutional neural network: denoiser overview



Solution: train with the Natural Image Noise Dataset



Denoising with a CNN trained on the NIND



Ground-truth

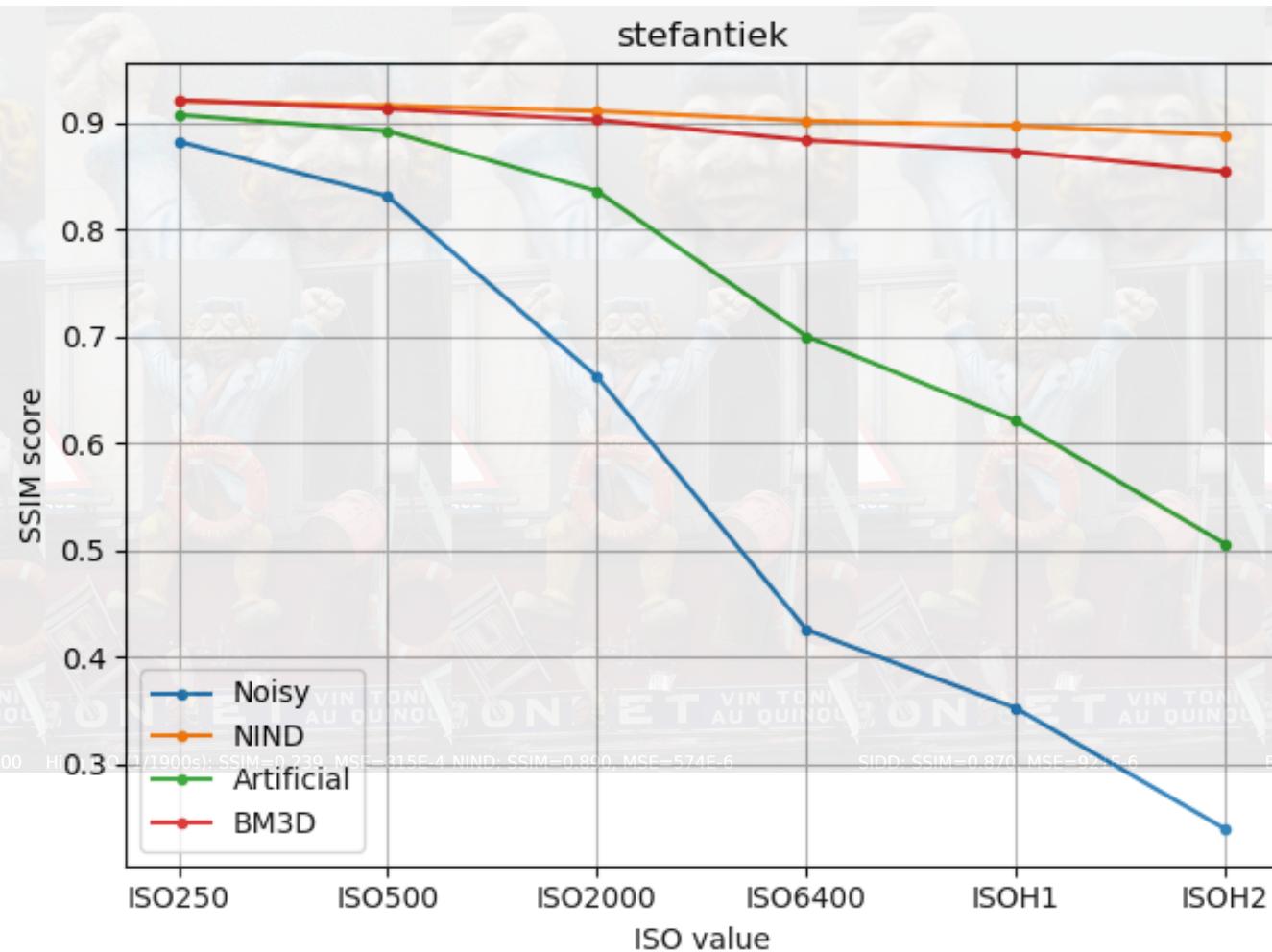
Noisy

U-Net w/NIND (ours)

BM3D



Denoising with a CNN trained on the NIND





Noisy



U-Net w/NIND



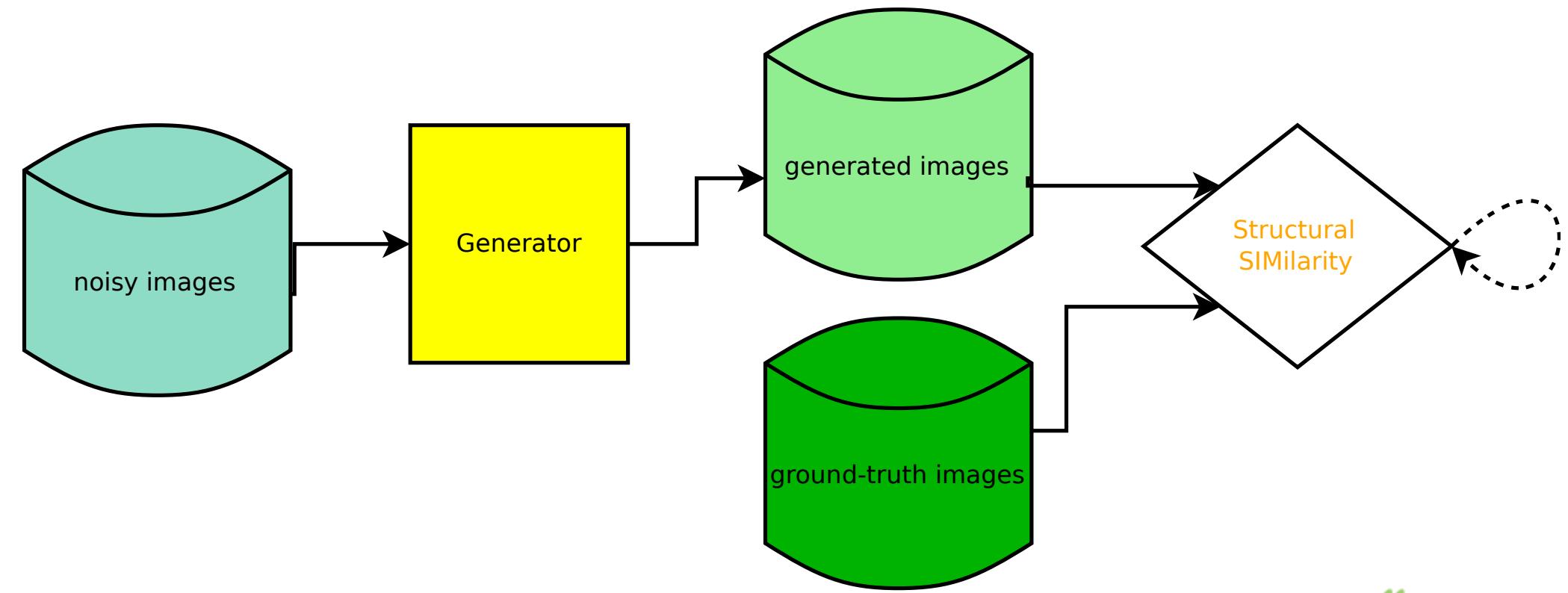
BM3D ($\sigma=30$)

Opens up new photographic possibilities

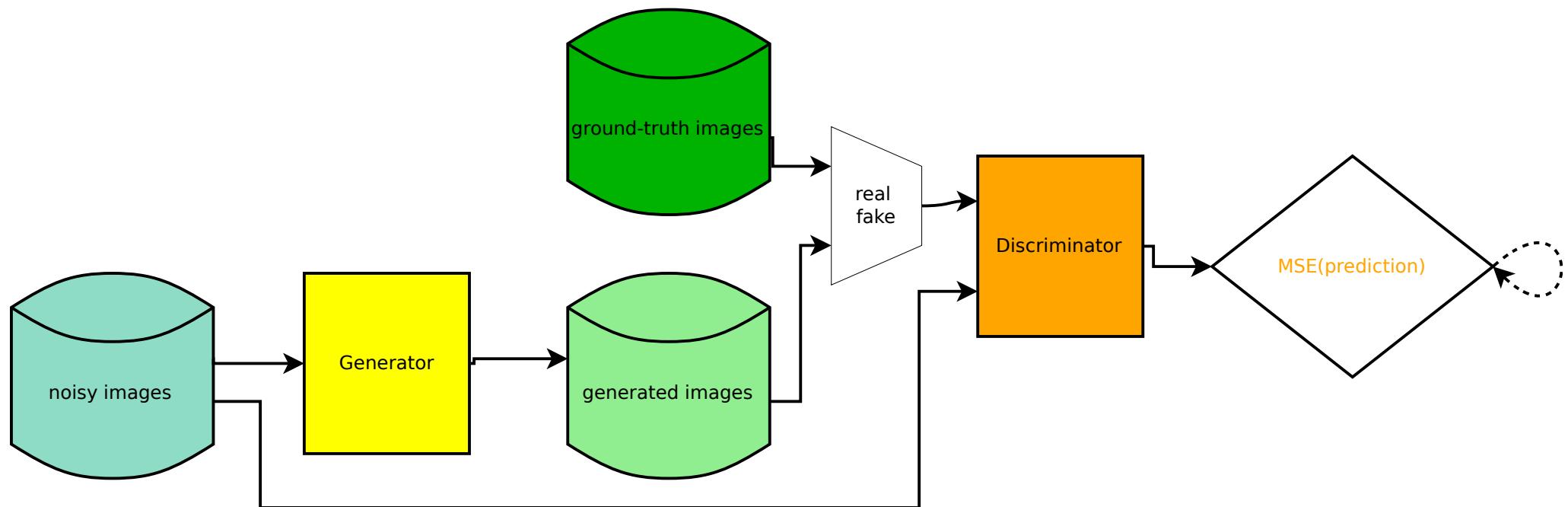
such as:
f/11 aperture
1/1500 sec.
ISO6400



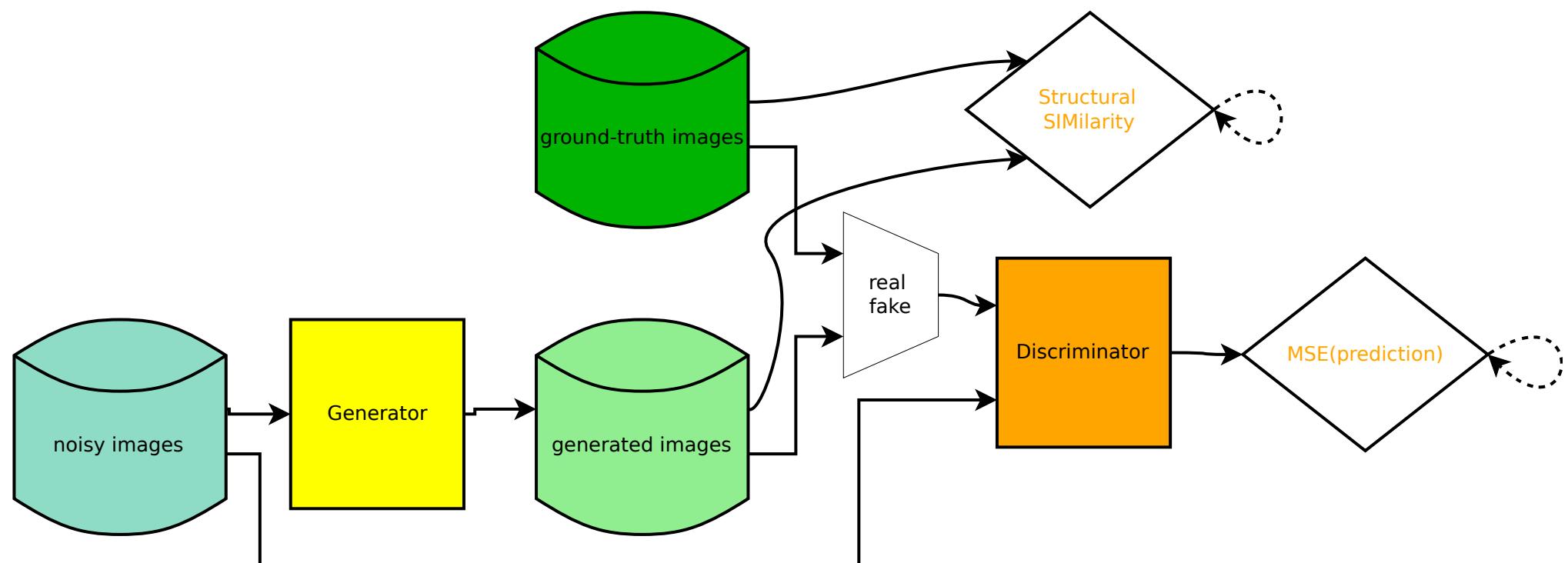
Can we improve performance further?



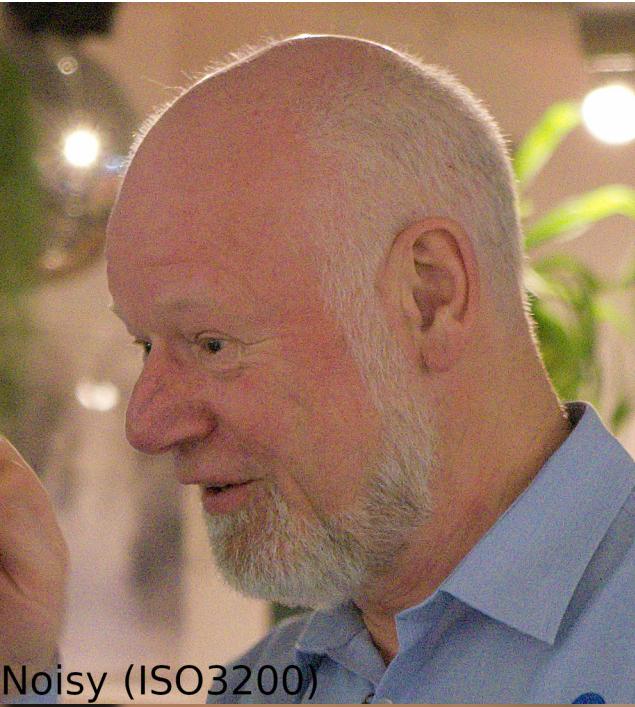
Conditional Generative Adversarial Network



Functional Conditional Generative Adversarial Network



Sample cGAN results



GAN takeaways

- GANs are much more difficult to train
 - Eg: mode collapse, unbalance, indecision, unnatural attributes
- Marginal improvement in most cases
- Apparent benefit in some cases (eg: high-frequencies)
- Possibility to train specialized networks (eg: paired discriminators, multiple losses, unpaired data)



Contributions

- Dataset of paired ground-truth – noisy images (NIND) to train neural networks for denoising
 - Benoit Brummer and Christophe De Vleeschouwer. “Natural Image Noise Dataset.” In: *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops*. 2019
- State-of-the-art denoising method using the NIND and a U-Net architecture
 - Delivered with model and stand-alone program to perform full-size image denoising
- Stable and effective method to train GANs for image denoising
 - Simple and stable scheduler, support for multiple discriminators and loss functions
 - Pair of generator / discriminator network architectures



Further research

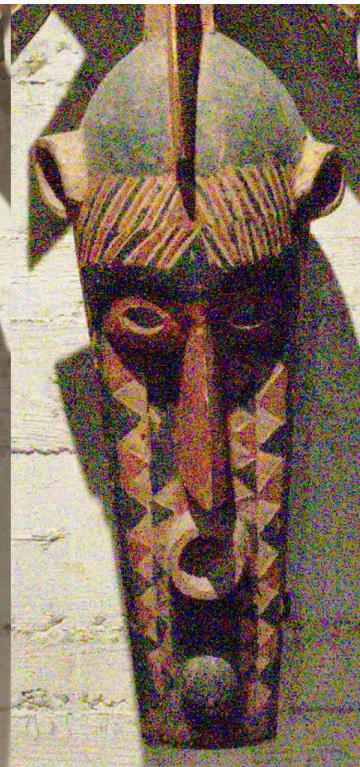
- Faster generative architecture
 - U-Net processes 1MP in 0.75 sec. on a GeForce GTX 1070
- Integration in open-source photo development software
 - s.a. Darktable, GMIC
- Specialized training for edge cases
 - Use non-paired data (eg: faces, wildlife)



Ground-truth
1 sec.



Noisy
1/170 sec.



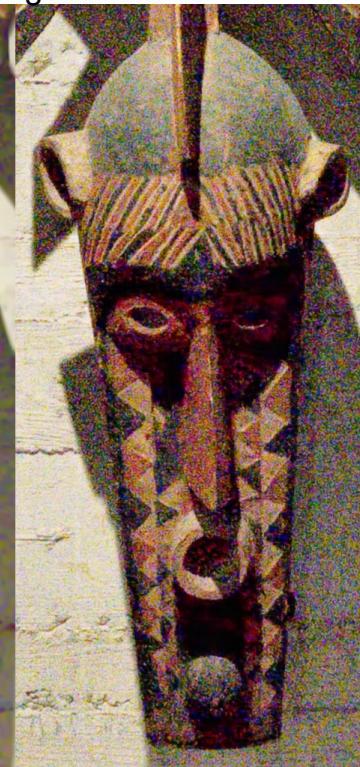
Non-local means
darktable sw implementation



BM3D
 $\sigma=99$



CNN
U-Net trained with
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CNN
U-Net trained on the
NIND

