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

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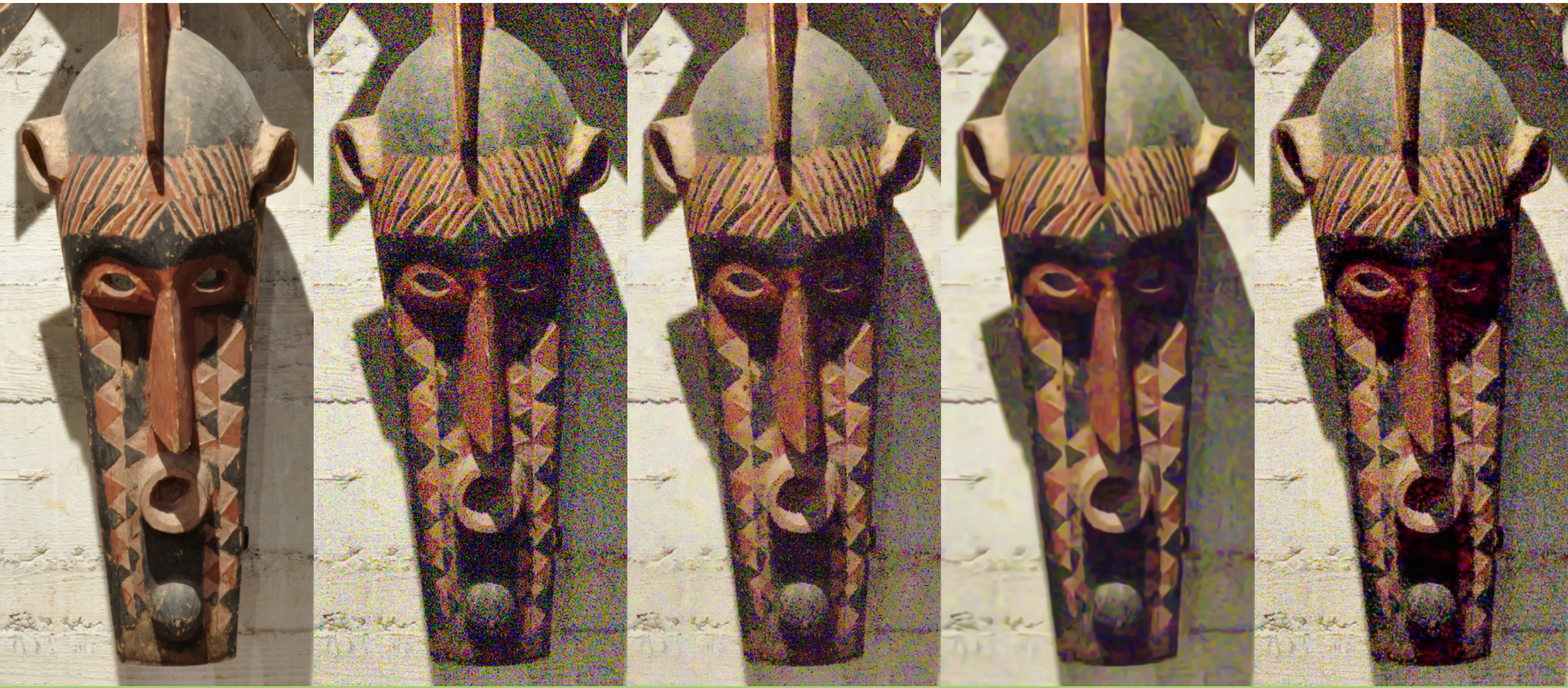
Problem: photographic image noise

Current solutions

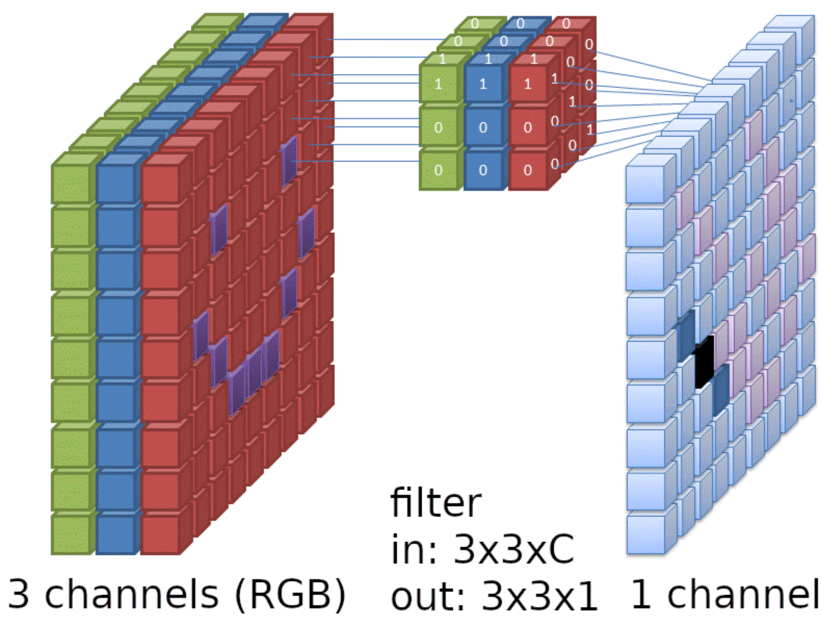
- Commonly used: non-local means, bilateral filter, wavelet, ...
- State-of-the-art: block-matching and 3D filtering (BM3D)
- Active research: convolutional neural networks



Ground-truth 1 sec.	Noisy 1/170 sec.	Non-local means darktable sw implementation	BM3D σ=99	CNN trained on gaussian noise

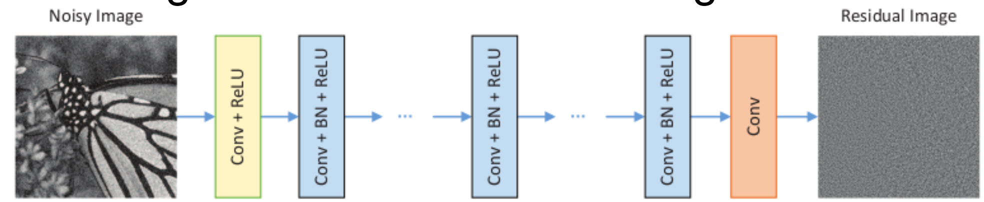
Convolutional neural networks

Main building block: convolution



Apply the same filter to every 3x3xC_{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)

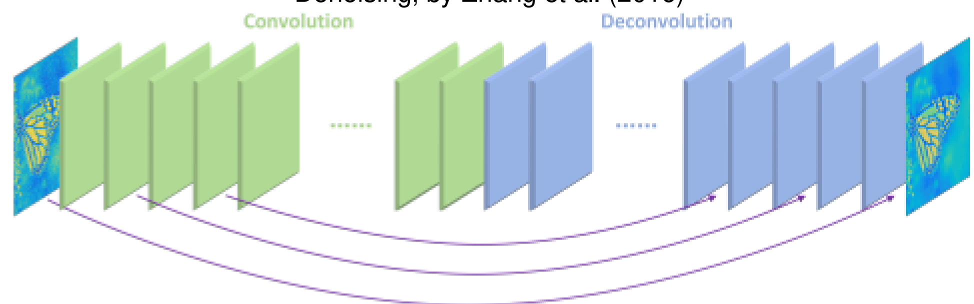
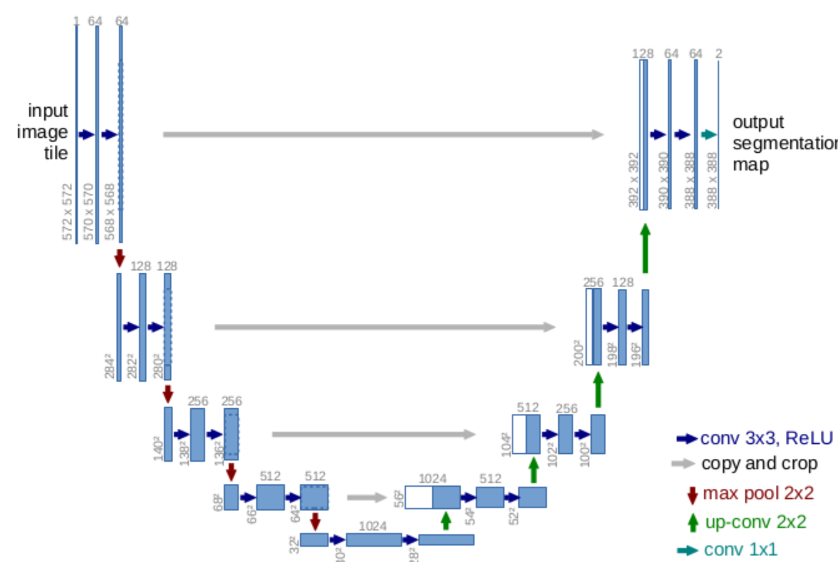
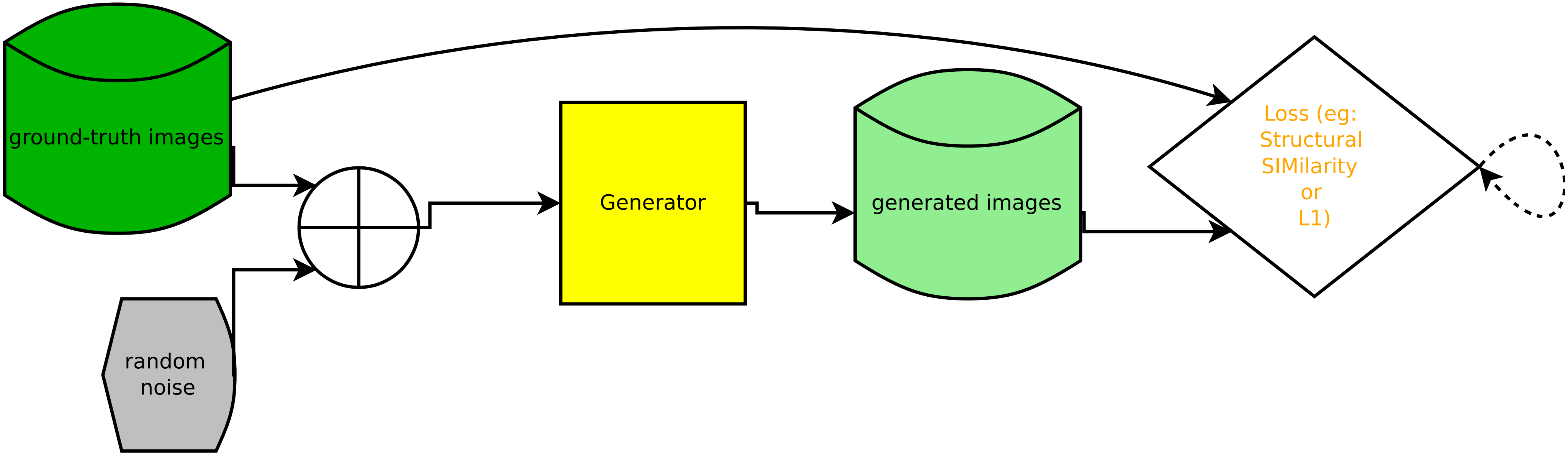


Image Restoration Using Very Deep Convolutional Encoder-Decoder Networks with Symmetric Skip Connections, by Mao et al. (2016)

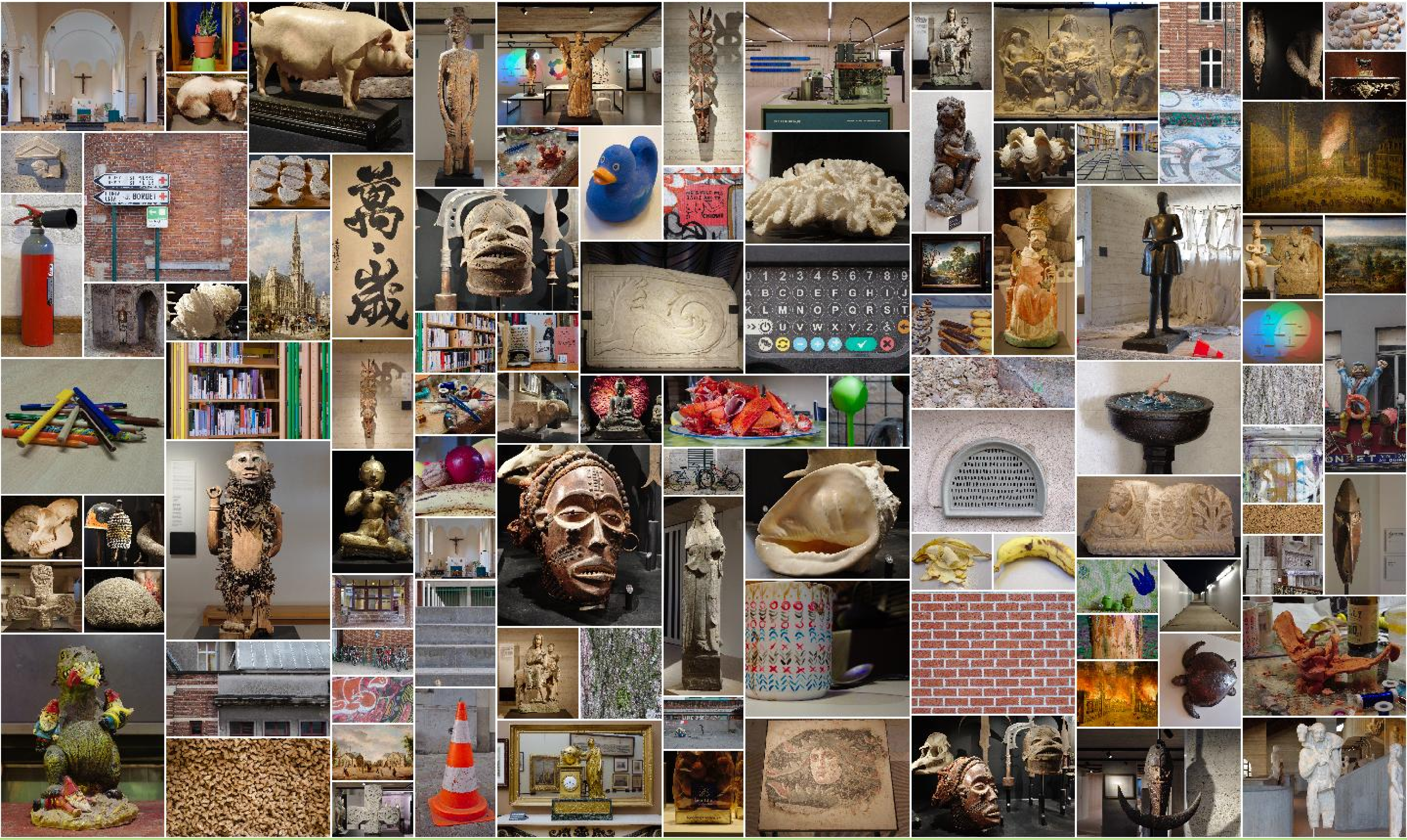


U-Net: Convolutional Networks for Biomedical Image Segmentation, by Ronneberger et al. (2015)

Convolutional neural network: denoiser overview



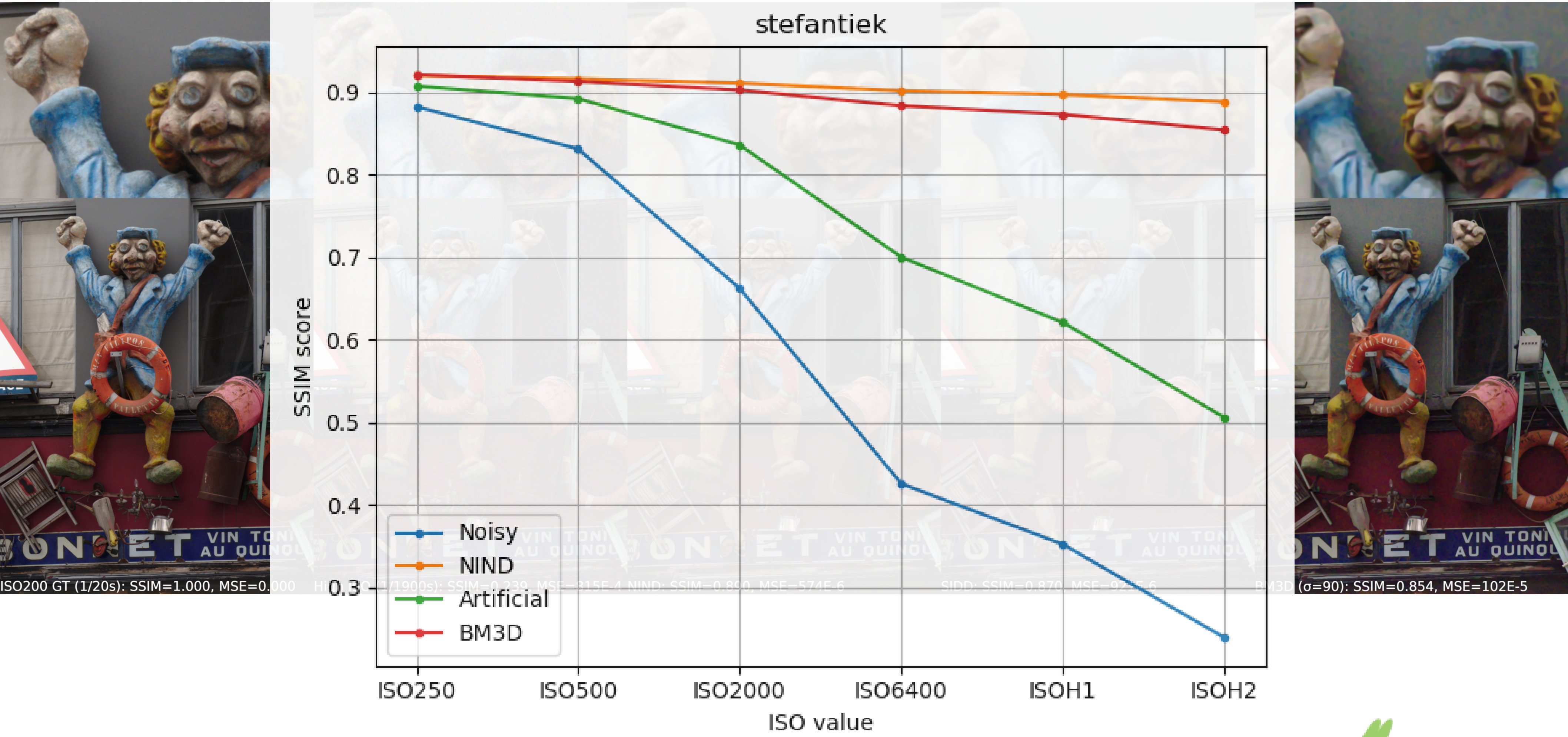
Solution: train with the Natural Image Noise Dataset



Denoising with a CNN trained on the NIND

Ground-truth | Noisy | U-Net w/NIND (ours) | BM3D

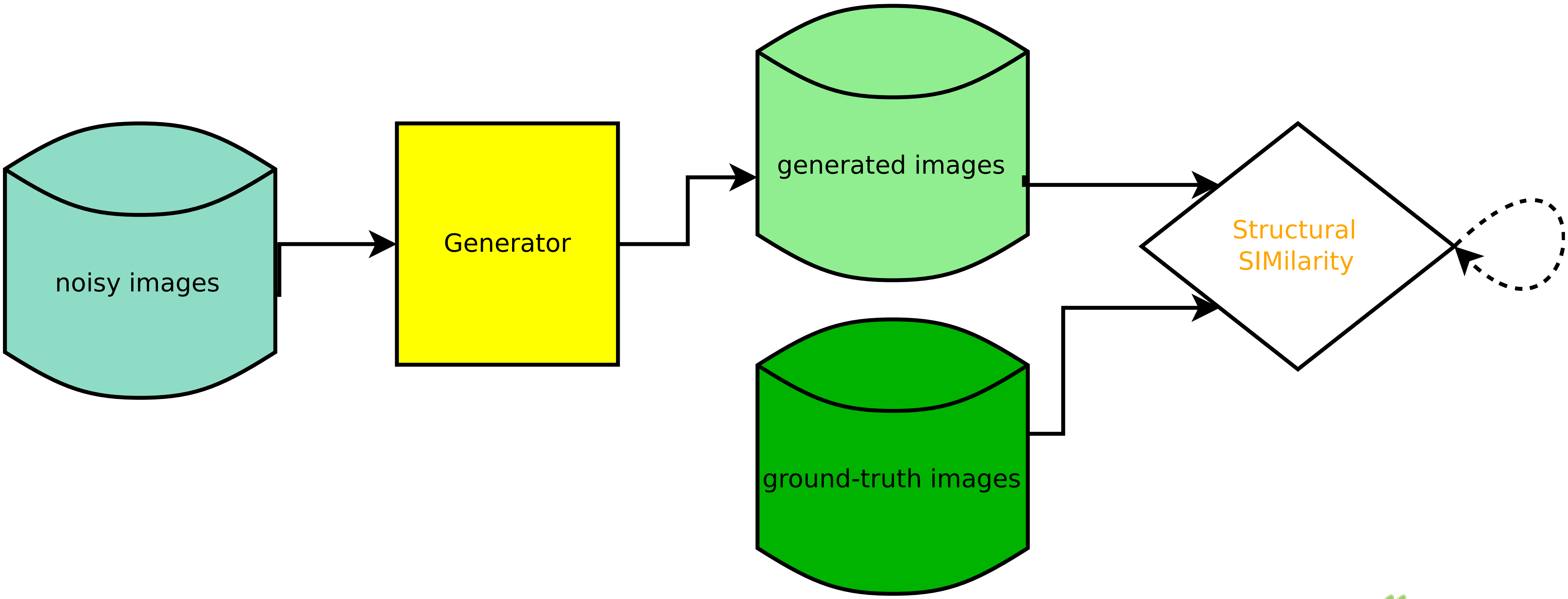
Denoising with a CNN trained on the NIND



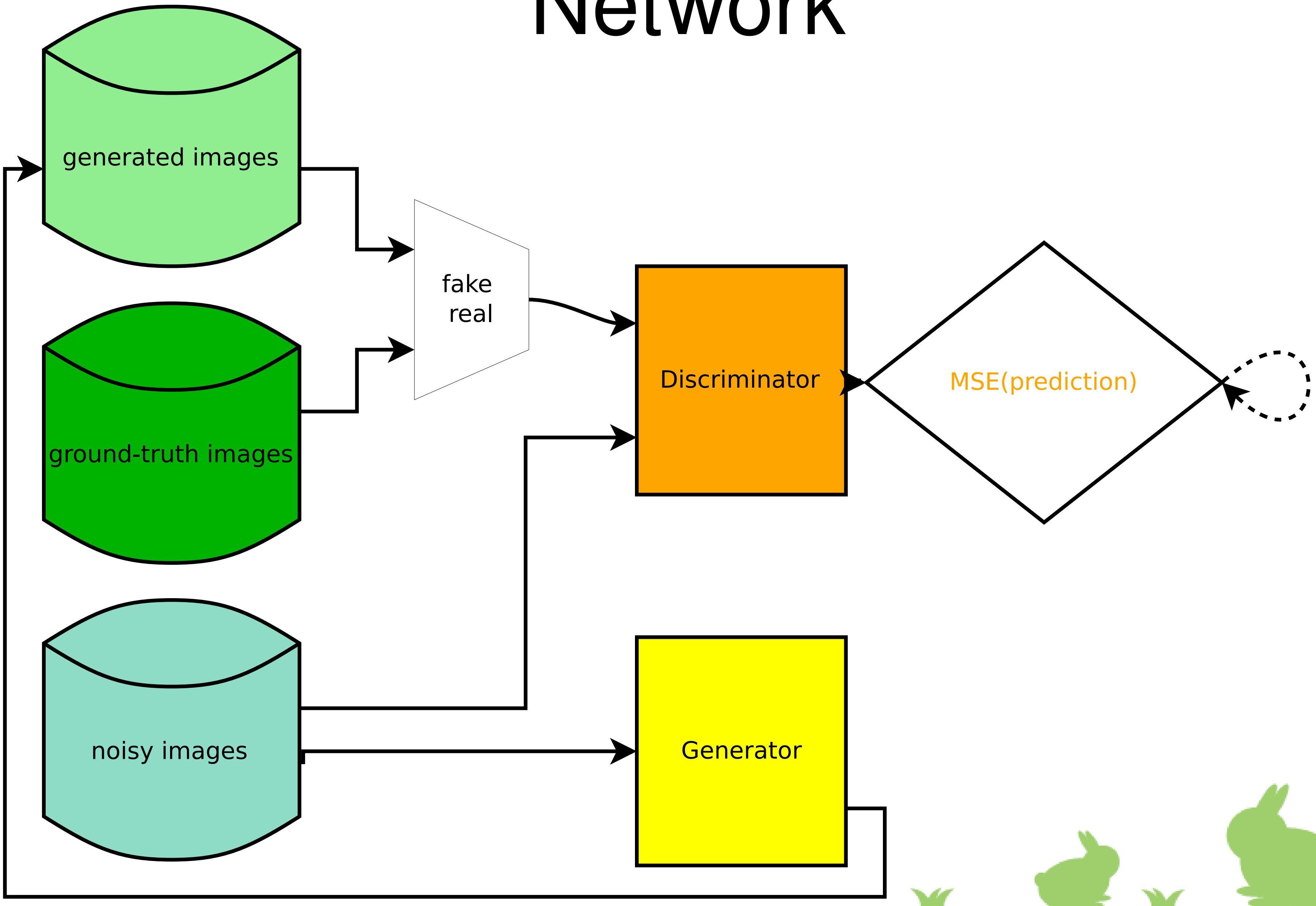
Opens up new photographic possibilities

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

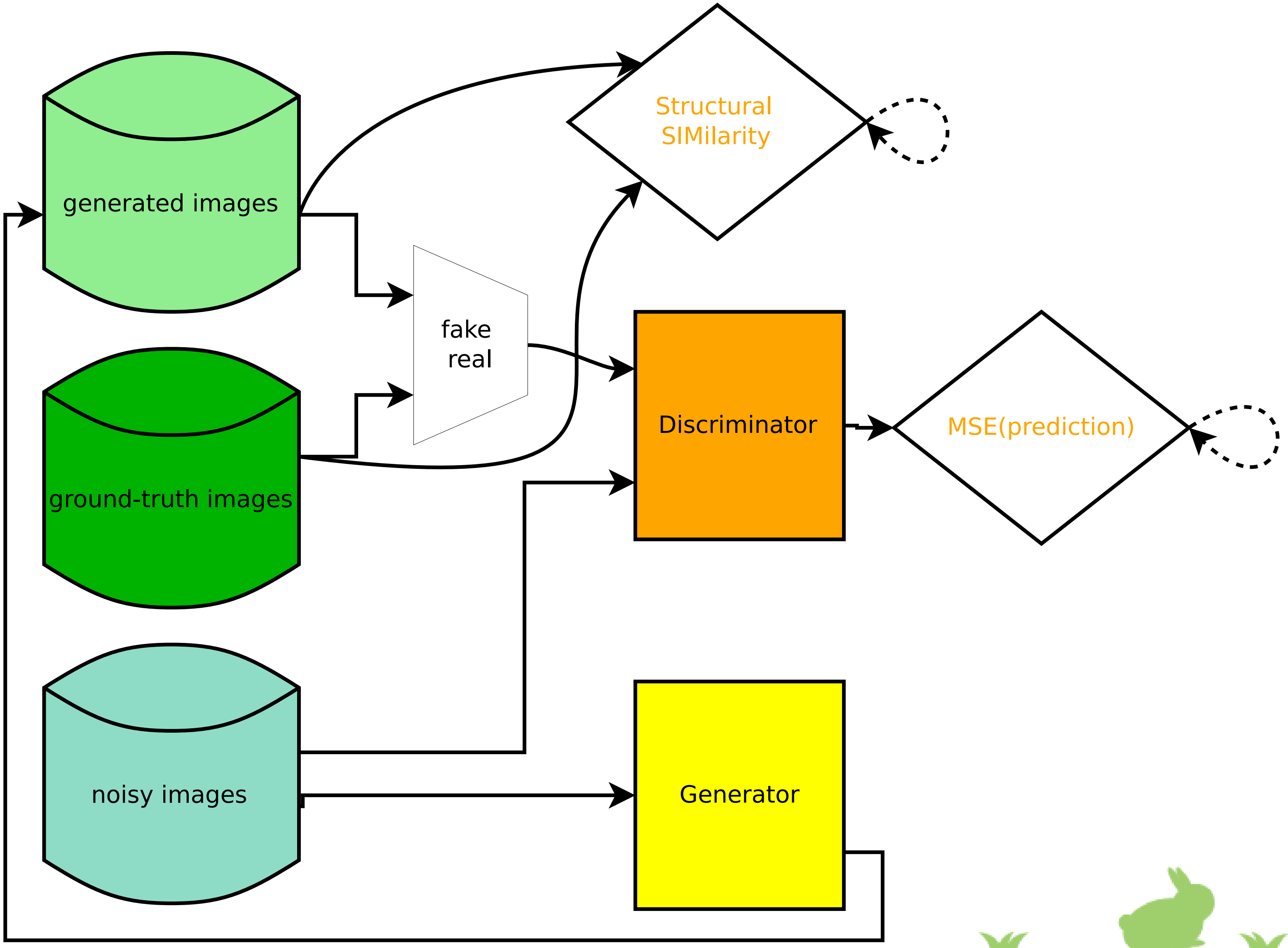
Can we improve performance further?



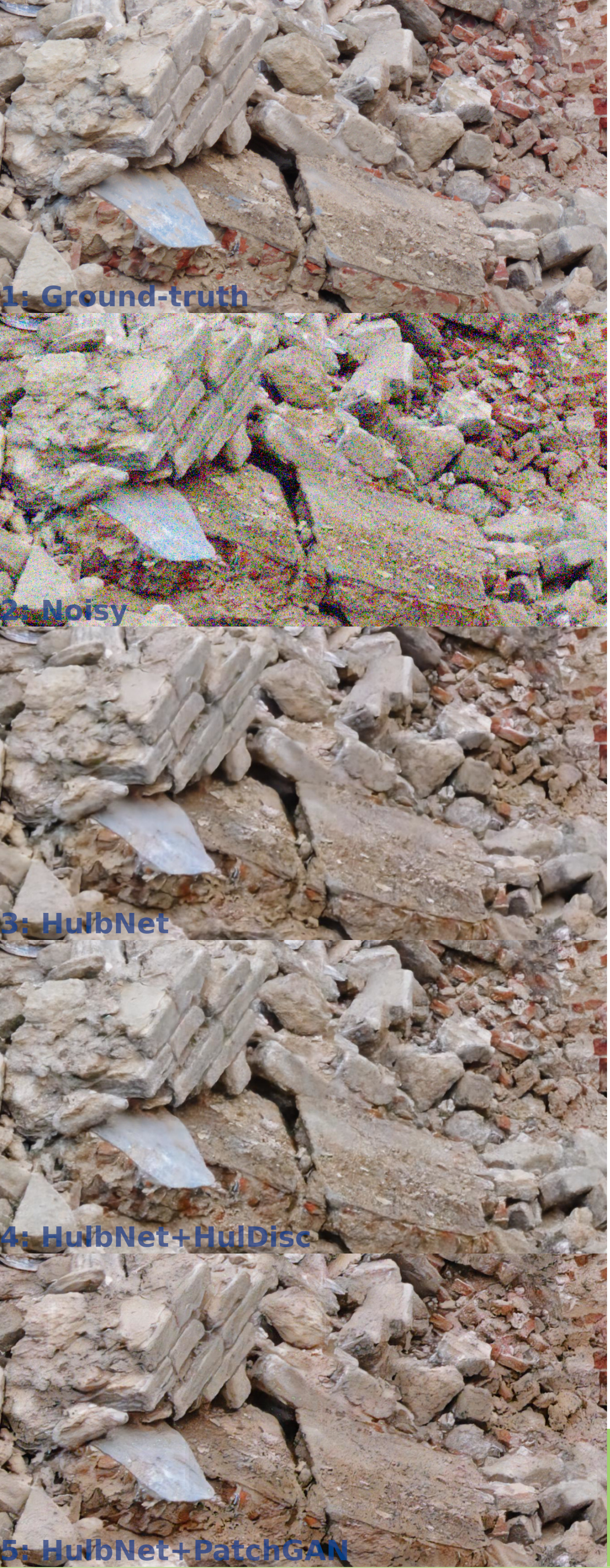
Conditional Generative Adversarial Network



Functional Conditional Generative Adversarial Network



Sample cGAN results

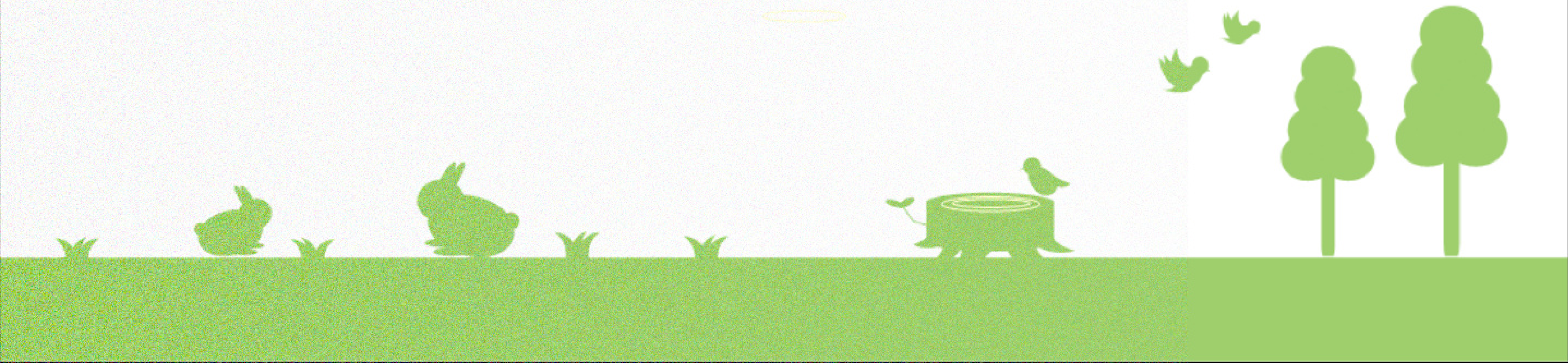


GAN takeaways

- 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
- 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)