

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

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Promoter: Christophe De Vleeschouwer

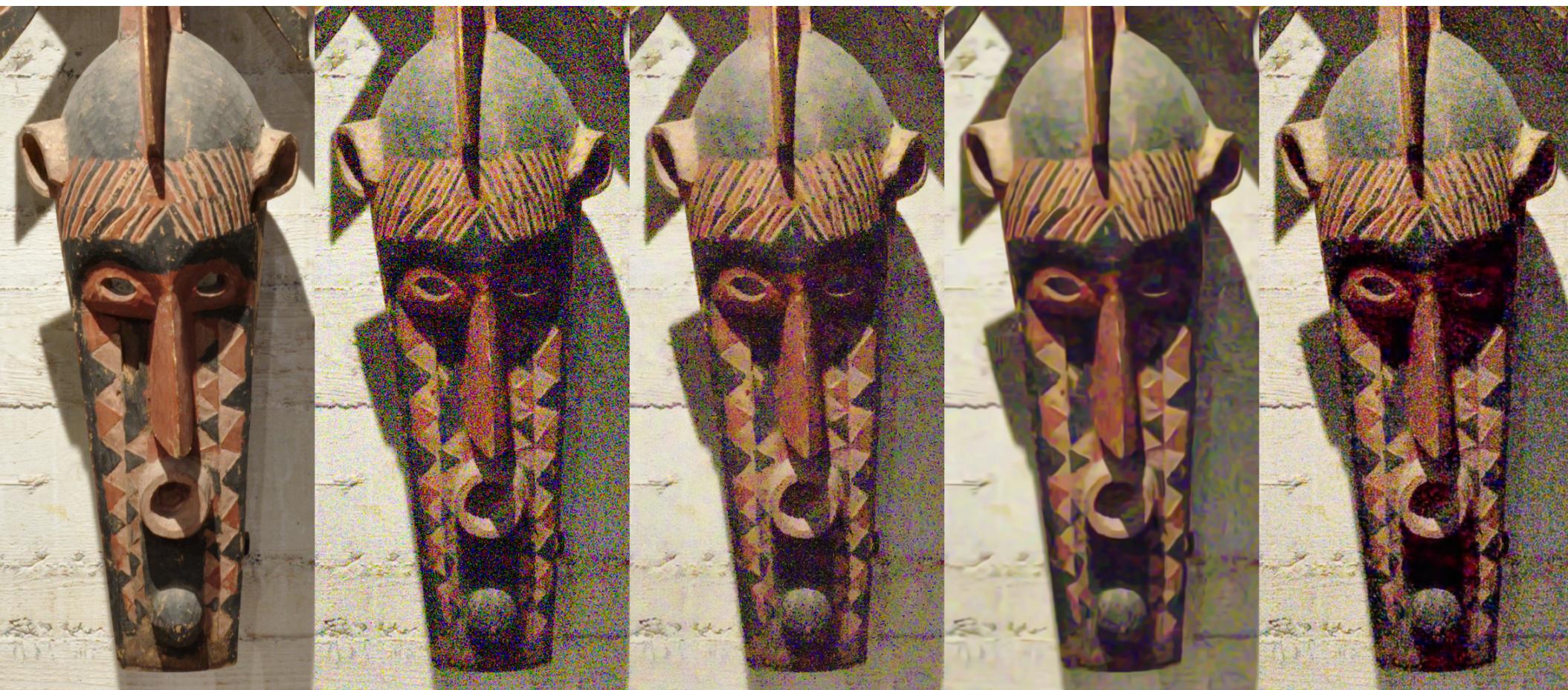


# Problem: photographic image noise



# 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.

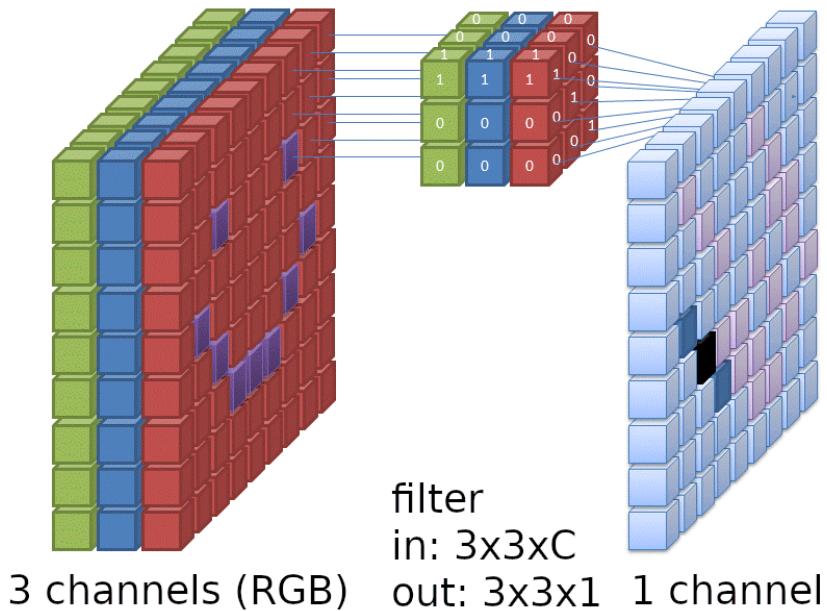
Non-local means  
darktable sw implementation

BM3D  
 $\sigma=99$

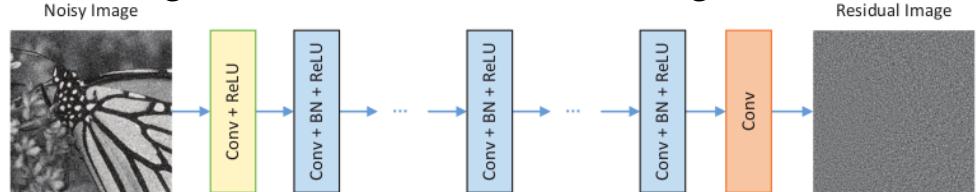
CNN  
trained on gaussian noise

# Convolutional neural networks

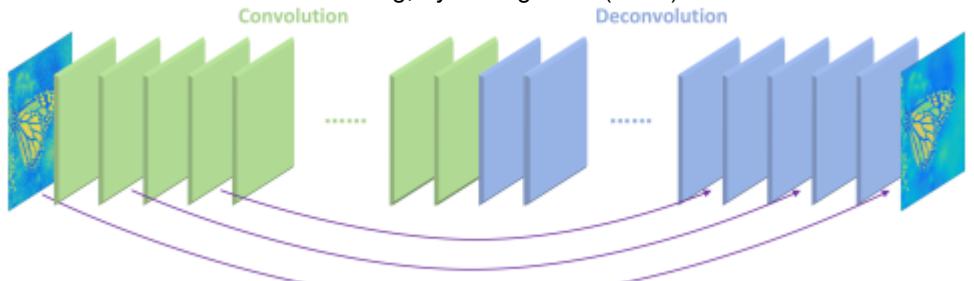
## Main building block: convolution



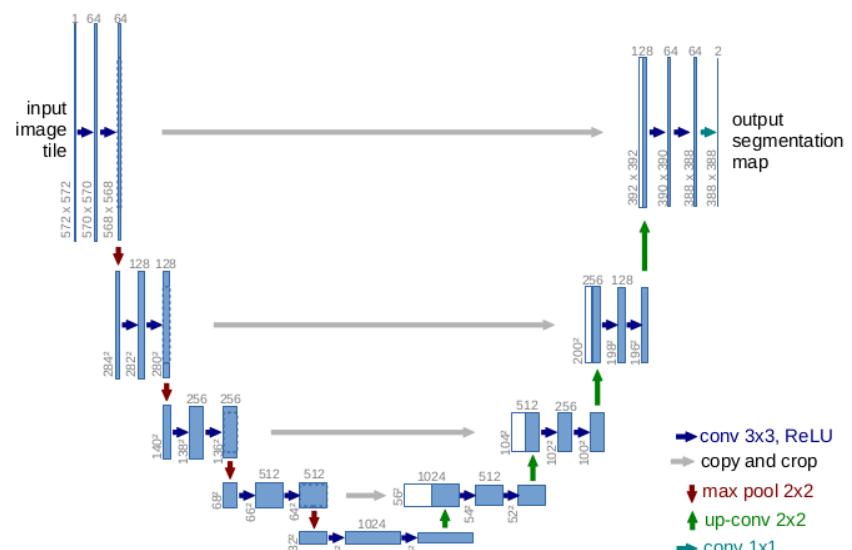
Apply the same filter to every  $3 \times 3 \times C_{in}$  area  
Repeat the process with different filters for  
 $C_{out}$  channels



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

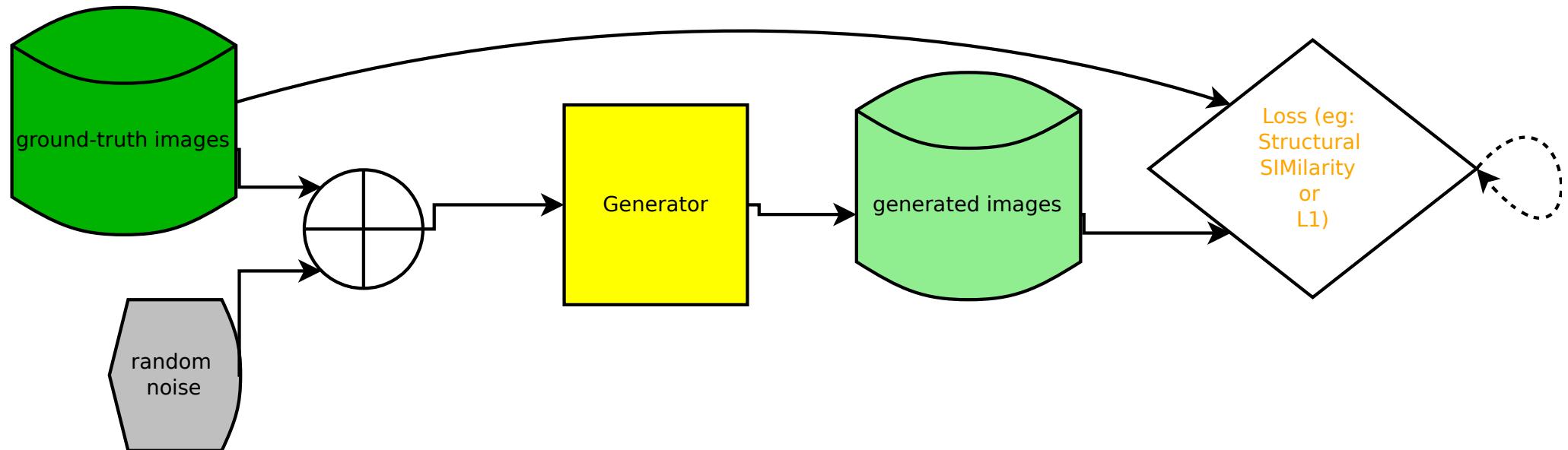


## Image Restoration Using Very Deep Convolutional Encoder-Decoder Networks with Symmetric Skip Connections, by Mao et al. (2016)

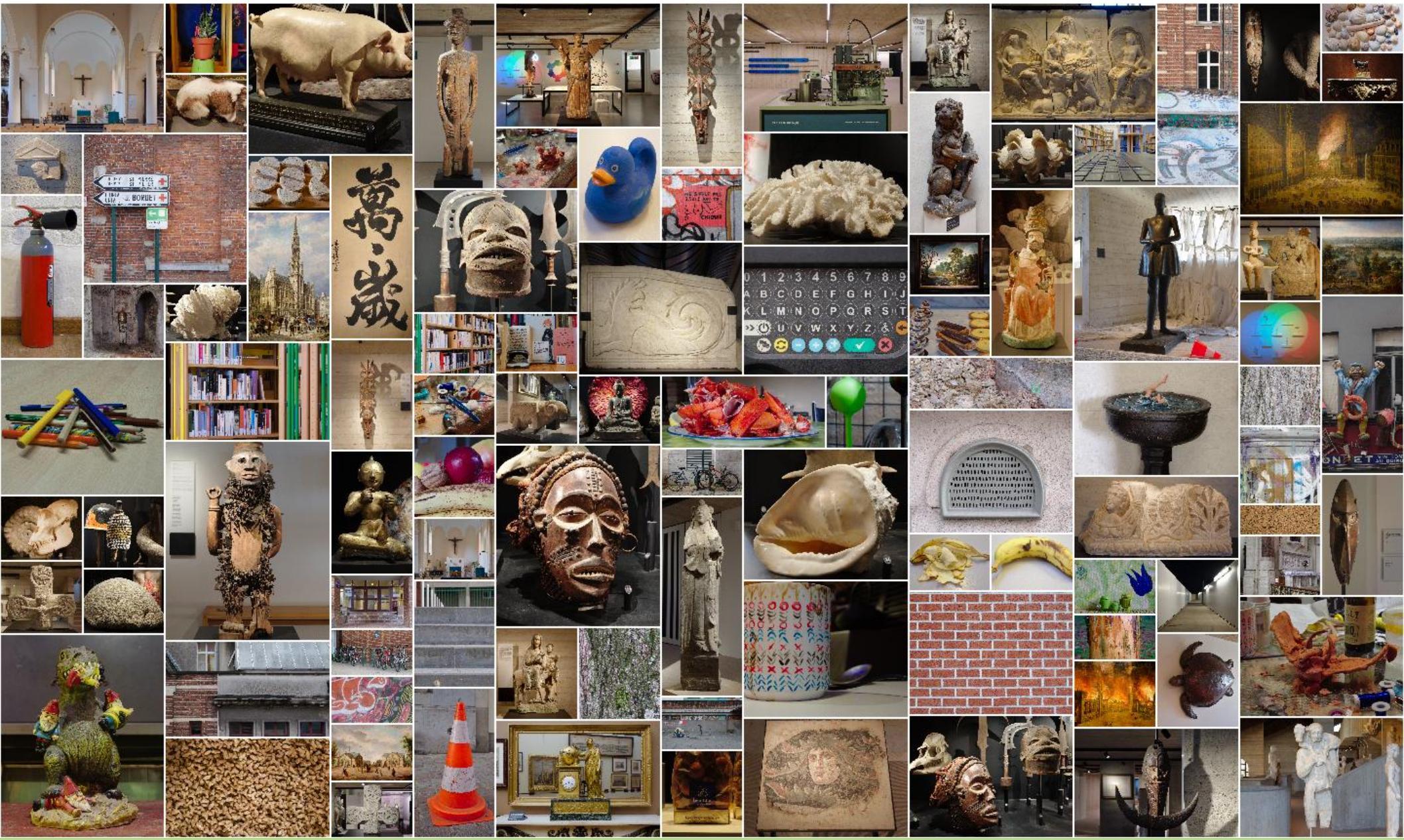


U-Net: Convolutional Networks for Biomedical Image Segmentation, by Ronneberger et al. (2015)

# Convolutional neural network: denoiser overview



# Solution: train with the Natural Image Noise Dataset



# Denoising with a CNN trained on the NIND



Ground-truth

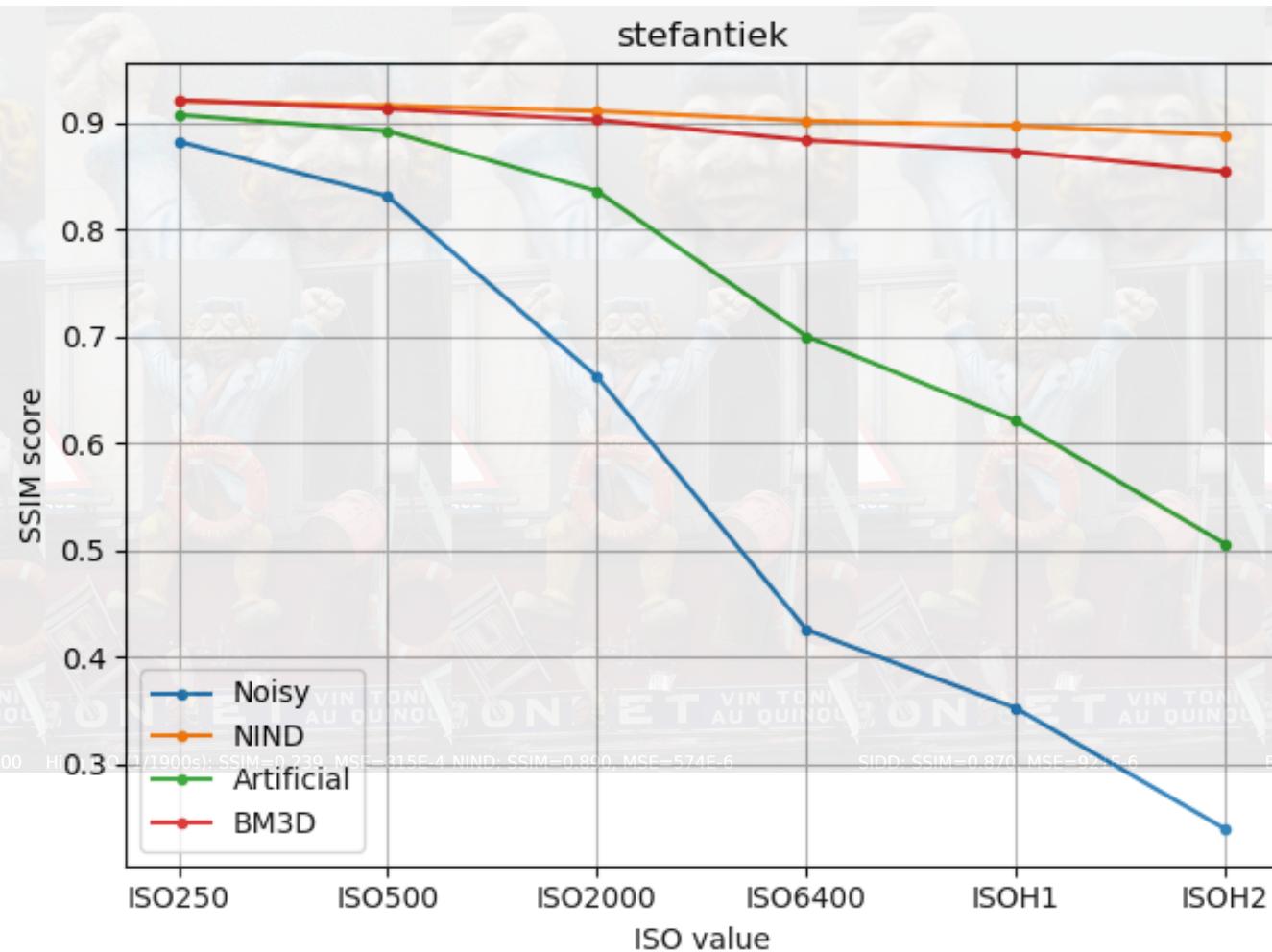
Noisy

U-Net w/NIND (ours)

BM3D



# Denoising with a CNN trained on the NIND



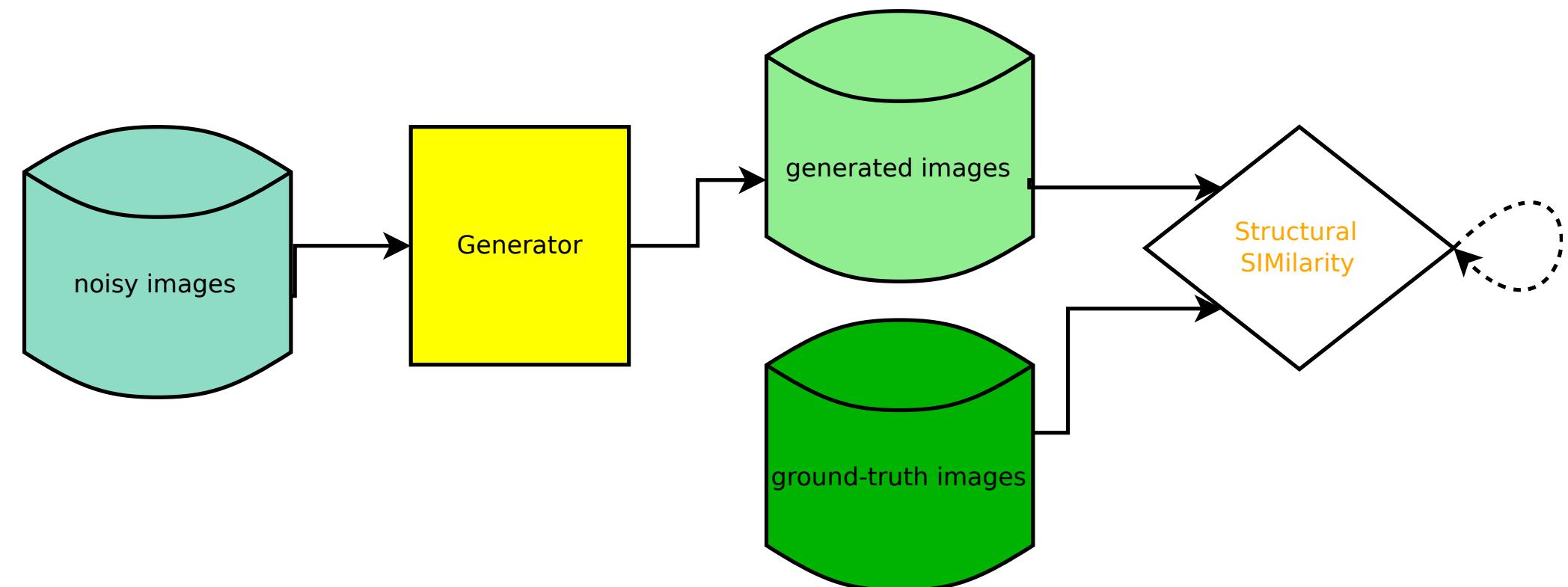


Opens up new photographic possibilities

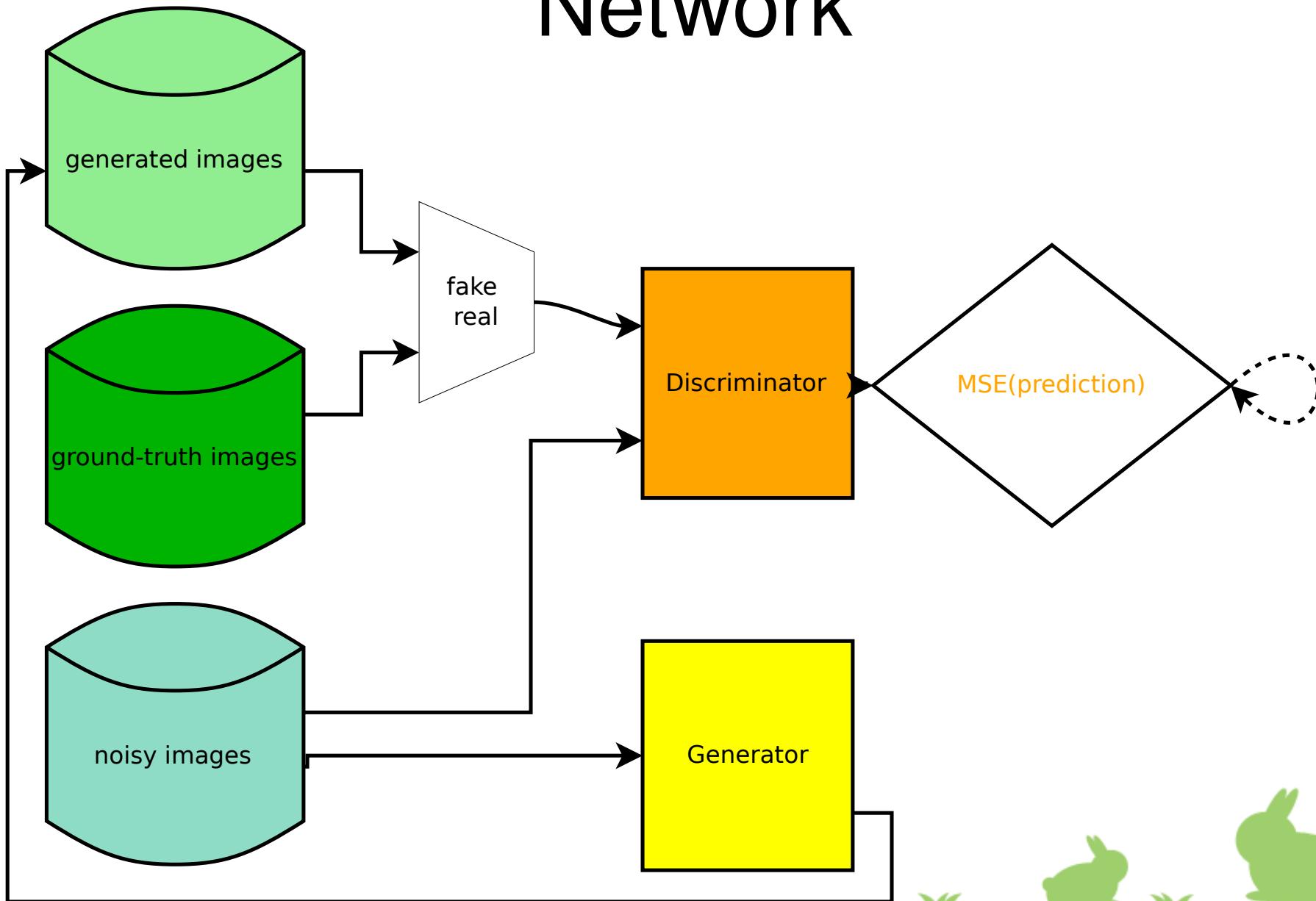
such as:  
f/11 aperture  
1/1500 sec.  
ISO6400



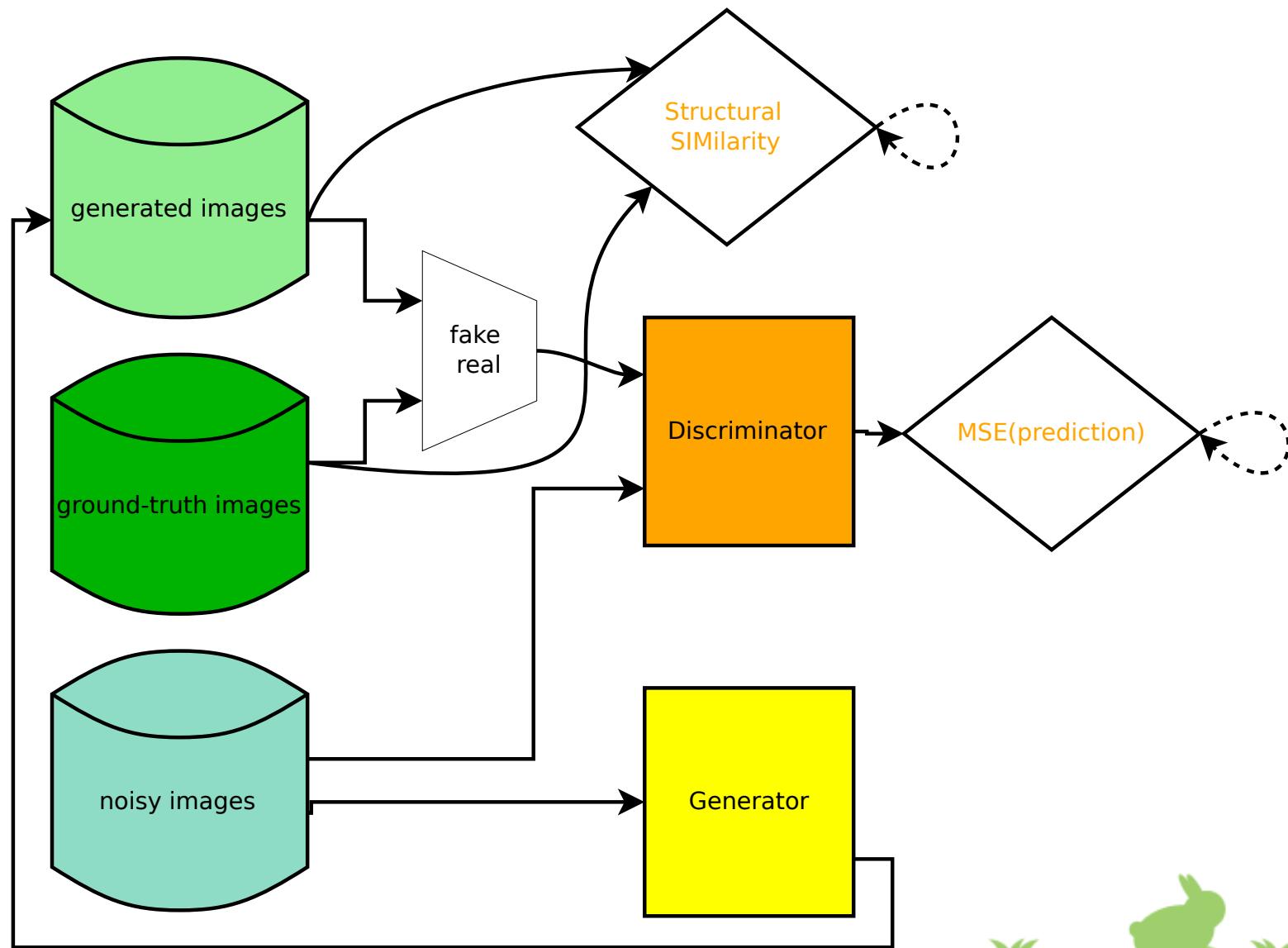
# Can we improve performance further?



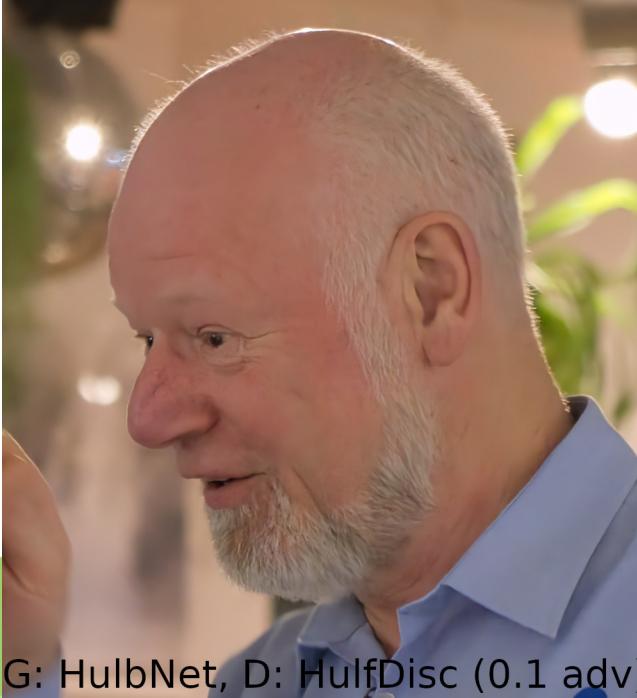
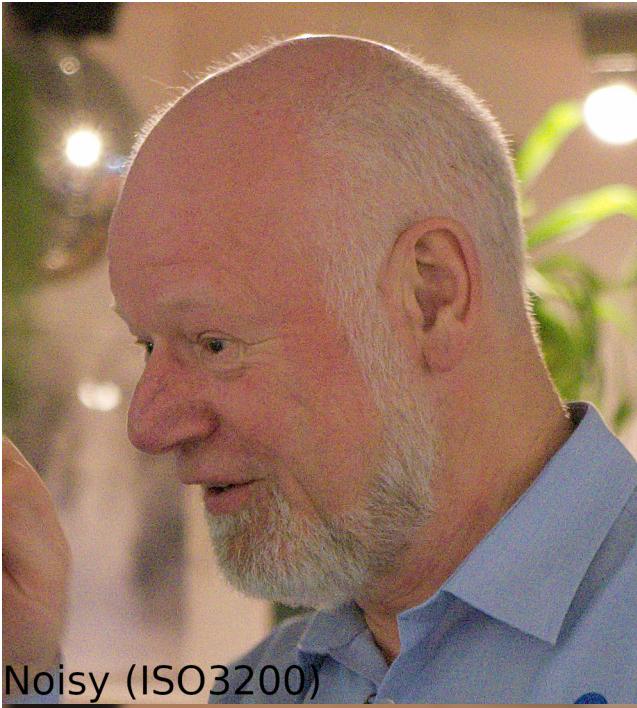
# Conditional Generative Adversarial Network



# 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)



