Understanding Deep Image Prior

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Inverse problems in imaging

$$\boldsymbol{x}_0 = d\left(\boldsymbol{x}_{gt}\right) + \boldsymbol{n}$$

- $\boldsymbol{x}_0$ . . . corrupted image
- $d(.)$ . . . degradation operator
- $\boldsymbol{x}_{gt}$ . . . clear ground-truth image
- $\boldsymbol{n}$ . . . noise

Denoising

- $d(.)$ is identity


Superresolution

- $d(.)$ is a downsampling operator

Inpainting

- $d(.)$ is Hadamard product with a binary mask of missing pixels


Deblurring

- $d(.)$ is a convolution with blur kernel


Task

Minimize $E(\boldsymbol{x}; \boldsymbol{x}_0) = ||d(\boldsymbol{x}) - \boldsymbol{x}_0|| + \mathcal{R}(\boldsymbol{x})$ w.r.t. $\boldsymbol{x}$

where $\mathcal{R}(\boldsymbol{x})$ stands for regularization (like total variation)

Deep image prior

A structure of a neural network is a prior itself.

Specifically, for inverse problems in imaging, its ConvNets.

Ulyanov et al., Deep Image Prior, 2018.

Task

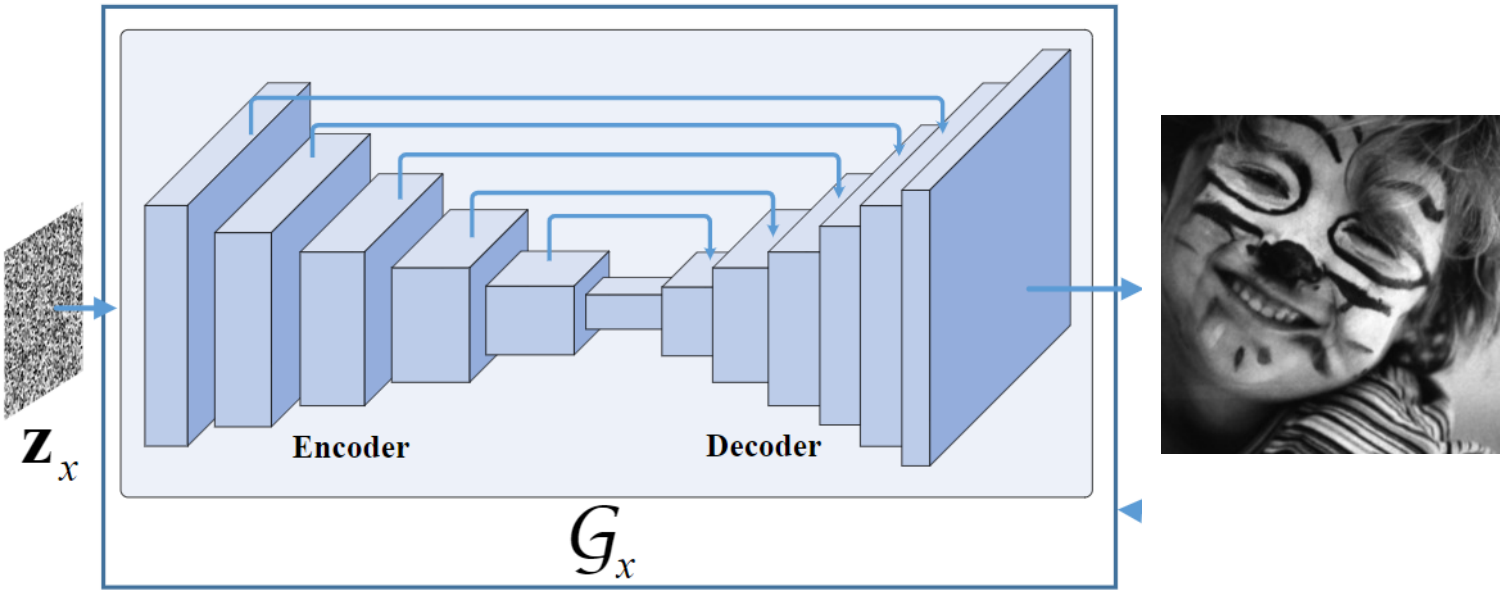
Minimize $E\left(f(\boldsymbol{\theta}|\boldsymbol{z}); \boldsymbol{x}_0\right) = ||d\left(f(\boldsymbol{\theta}|\boldsymbol{z})\right) - \boldsymbol{x}_0||$ w.r.t. $\boldsymbol{\theta}$,

where $f\left(\boldsymbol{\theta}|\boldsymbol{z}\right)$ stands for a neural network with trainable parameters $\boldsymbol{\theta}$ and input array $\boldsymbol{z}$.

Solution is $\boldsymbol{x} = f(\boldsymbol{\theta}|\boldsymbol{z})$

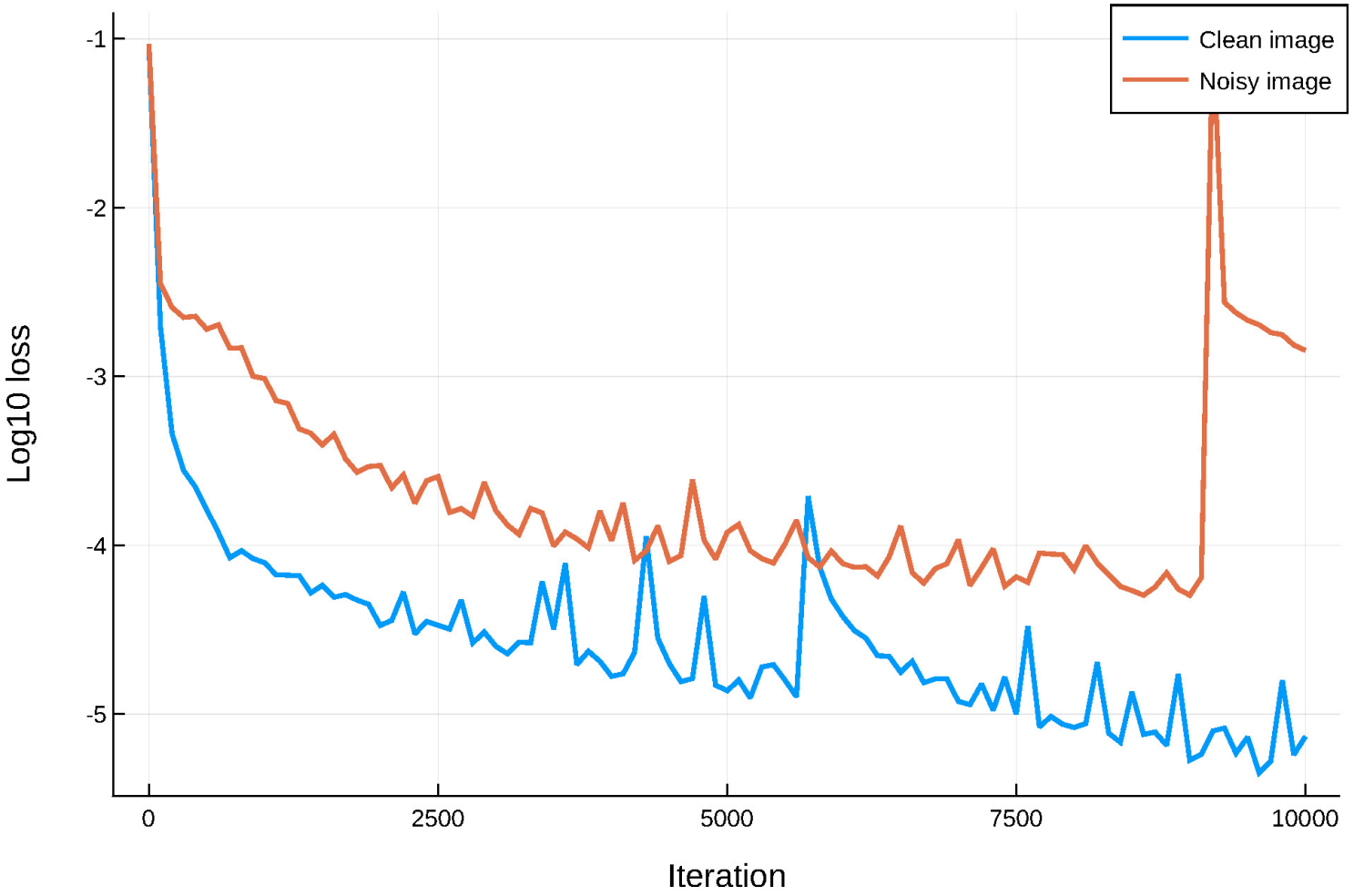
Overparametrization?

Commonly used U-net with 5 levels and skip connections contains 2mil trainable parameters

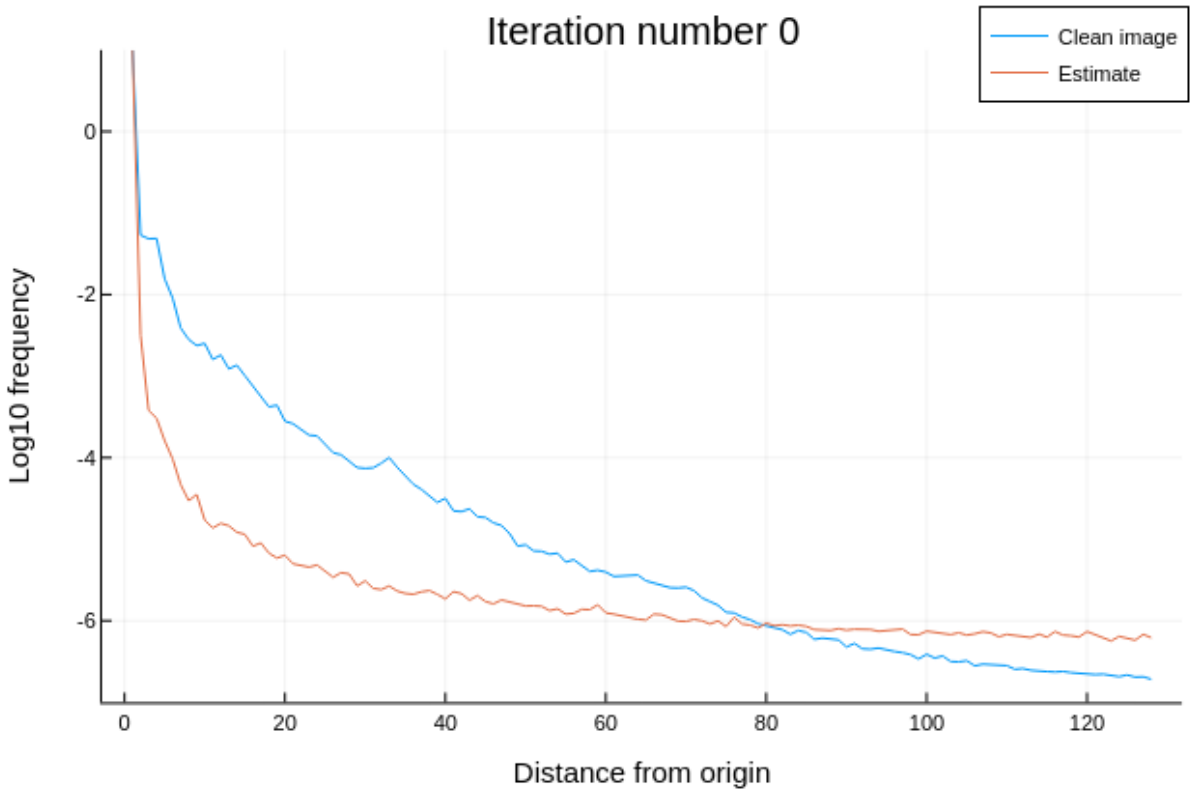


Ren et al., Neural Blind Deconvolution Using Deep Priors, 2020

High impedance to noise

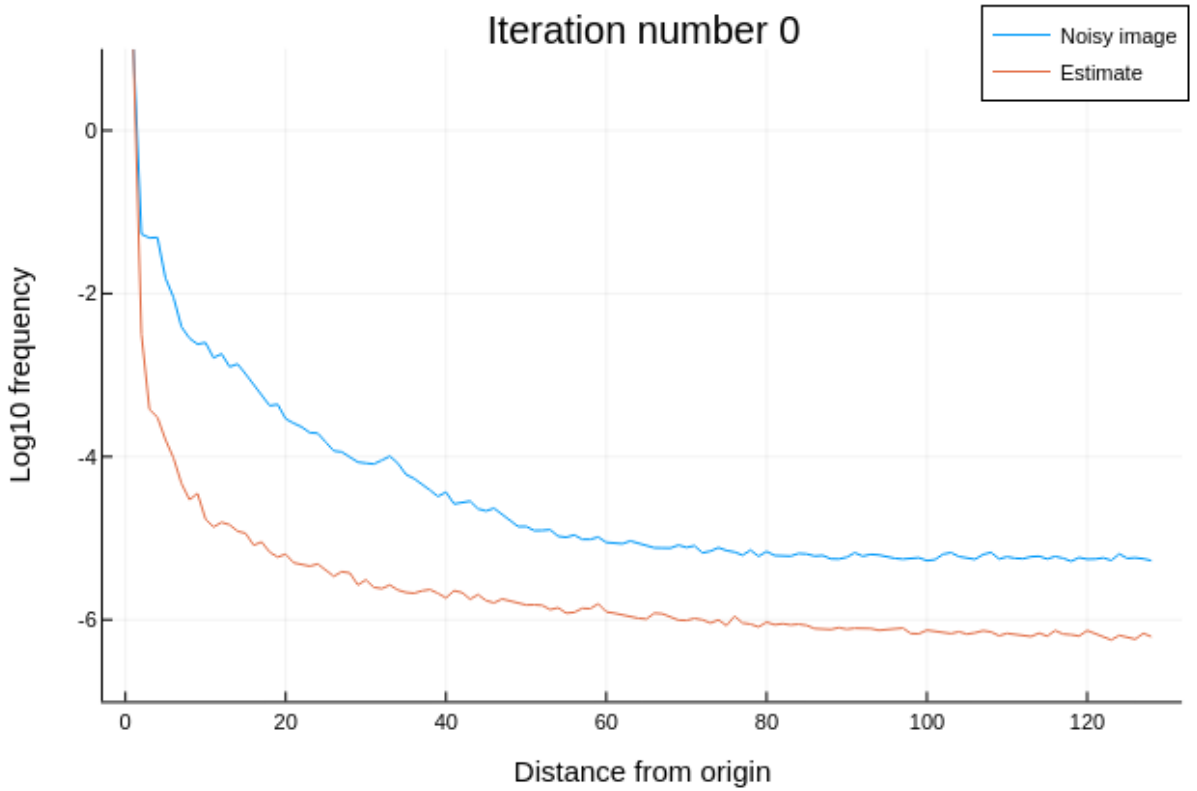


Power spectral density - clean image

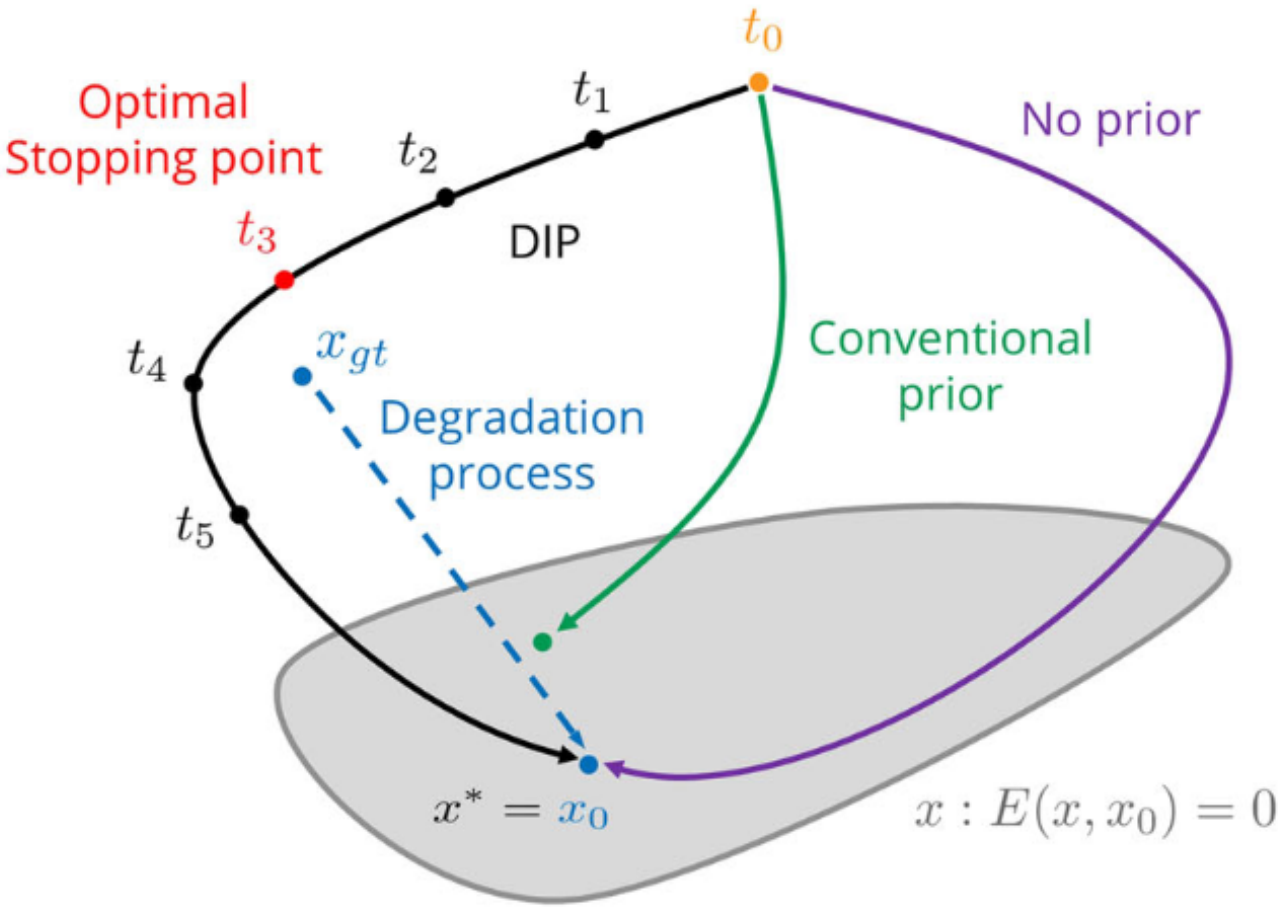


Shi et al., On Measuring and Controlling the Spectral Bias of the Deep Image Prior, 2022.

Power spectral density - noisy image

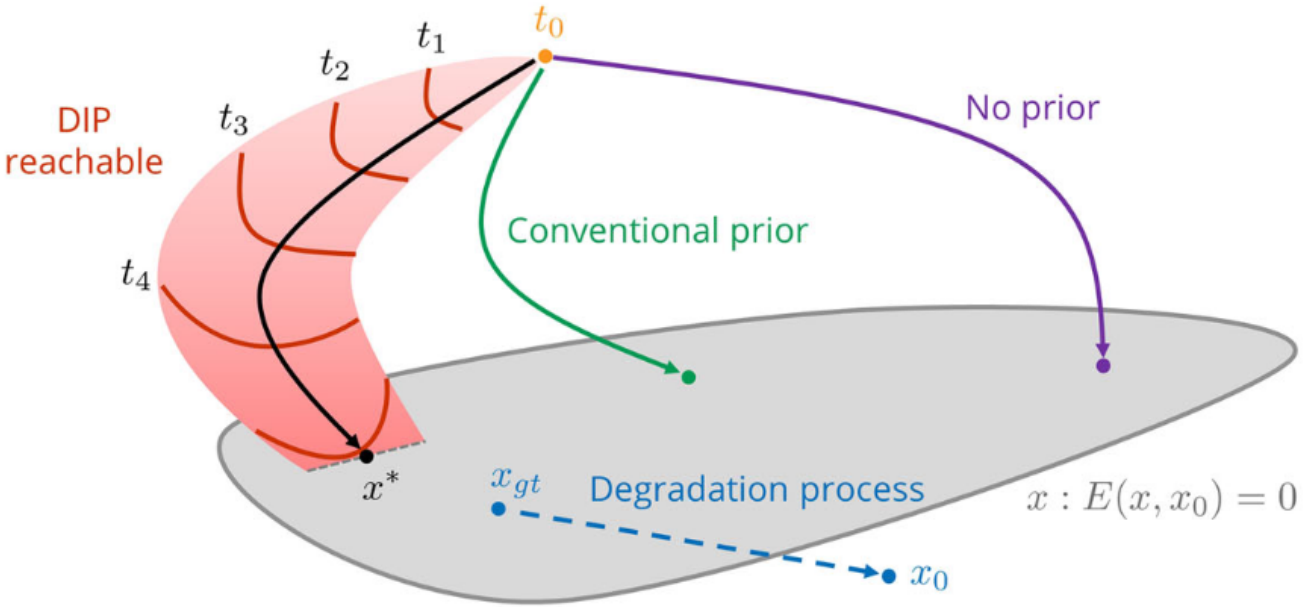


Early-stopping for denoising



Ulyanov et al., Deep Image Prior, 2020.

Other inverse problems



Ulyanov et al., Deep Image Prior, 2020.

How to choose the architecture

- Problem dependent
- Image dependent
- Does not necessarily have to be overparametrized
- Convolutions
- Upsampling

Issues

- Initialization of the network
- Initialization of the noise array
- Probably still not universal
- Regularization