EPFL

electronic IMAGING 2022 JANUARY

Image Denoising with Control over Deep Network Hallucination

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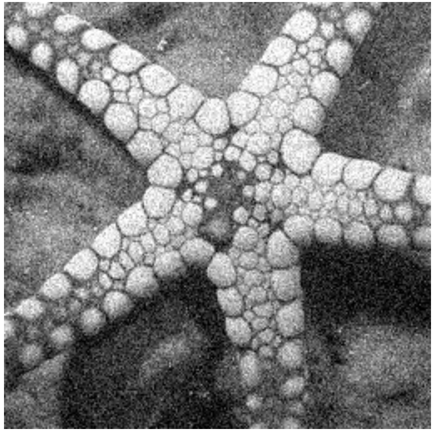
Introduction
Denoising I Problem

- Additive white Gaussian noise



Noisy image

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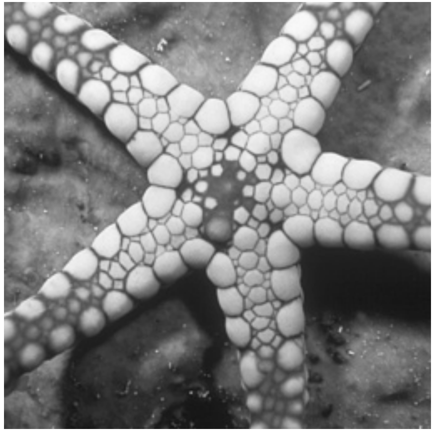
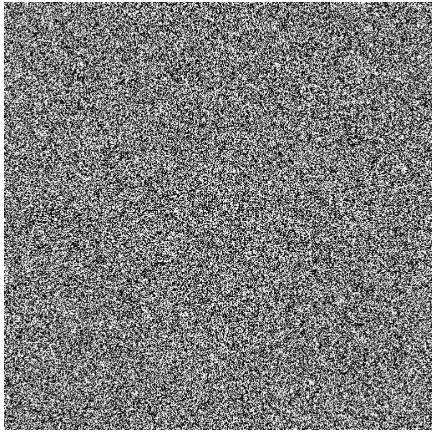


Clean image

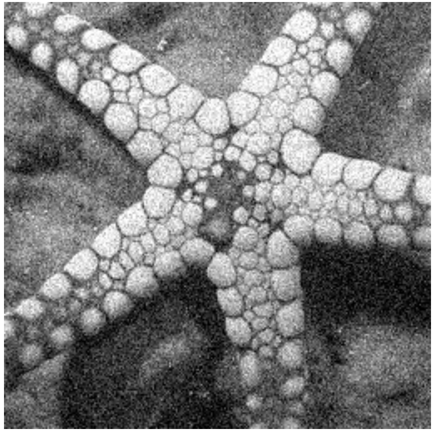
+



White Gaussian noise

Introduction
Denoising I Solution

- State-of-the-art in quantitative reconstruction: deep learning (DL)



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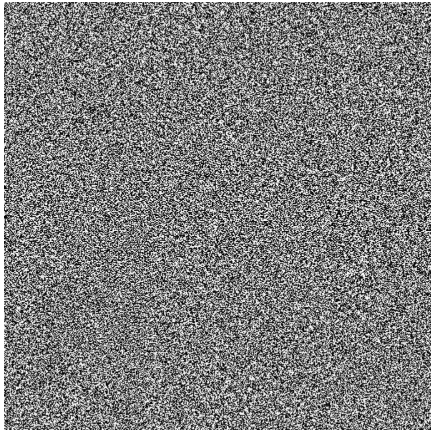

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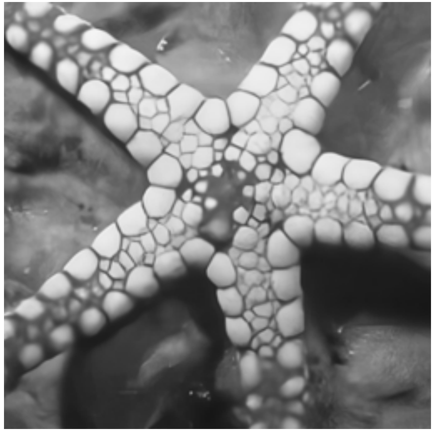


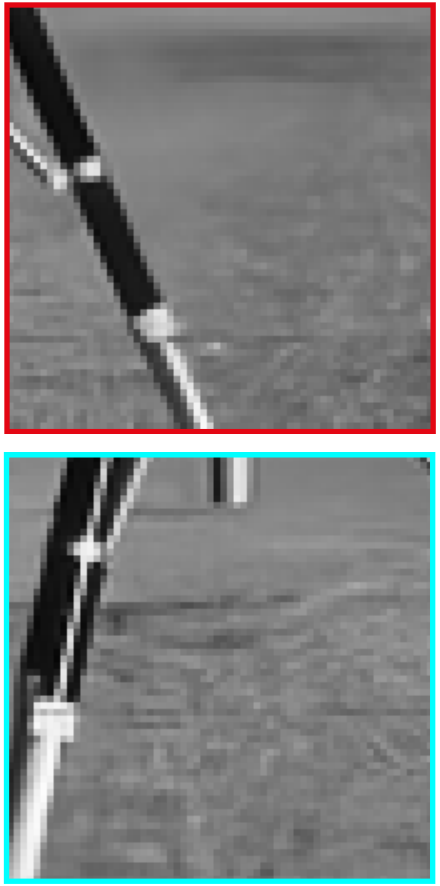
Noisy image | Predicted noise | Denoised image

Motivation
Interpretability

- Sample denoised image using DnCNN[1] trained on $\sigma = 25$, tested on $\sigma = 25$


Noisy image

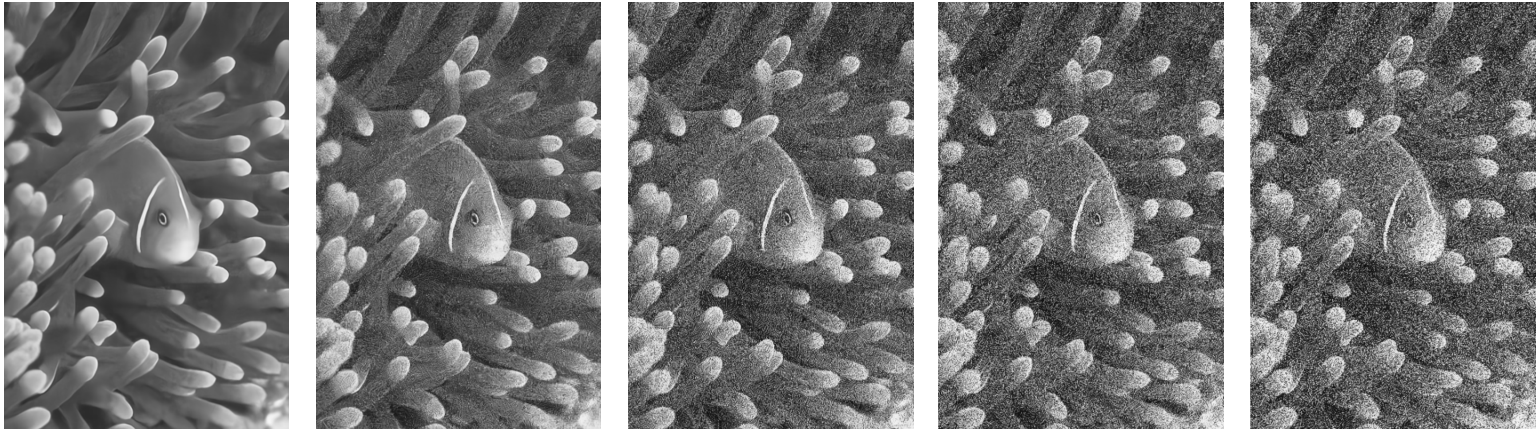

DL Denoised image


Zoomed-in

[1]Kai Zhang, Wangmeng Zuo, Yunjin Chen, Deyu Meng, and Lei Zhang. Beyond a Gaussian denoiser: Residual learning of deep CNN for image denoising. IEEE Transactions on Image Processing, 26(7):3142–3155, 2017.

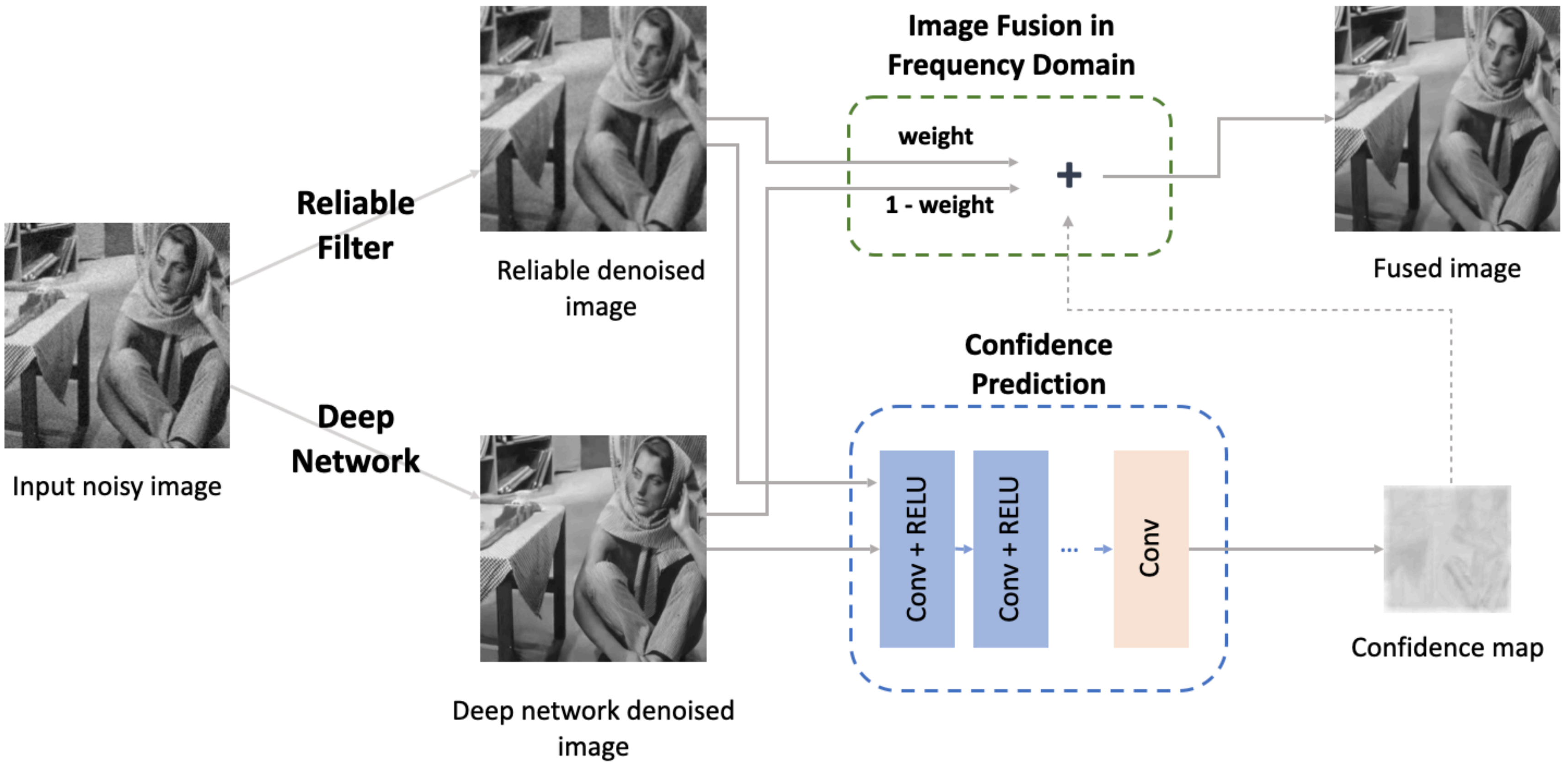
Motivation
Generalization

- Sample denoised images using DnCNN trained on $\sigma = 25$, tested on $\sigma \in \{25, 35, 45, 55, 65\}$



$\sigma = 25$ $\sigma = 35$ $\sigma = 45$ $\sigma = 55$ $\sigma = 65$

Proposed Method
CCID Pipeline



Proposed Method

CCID I Interpretability

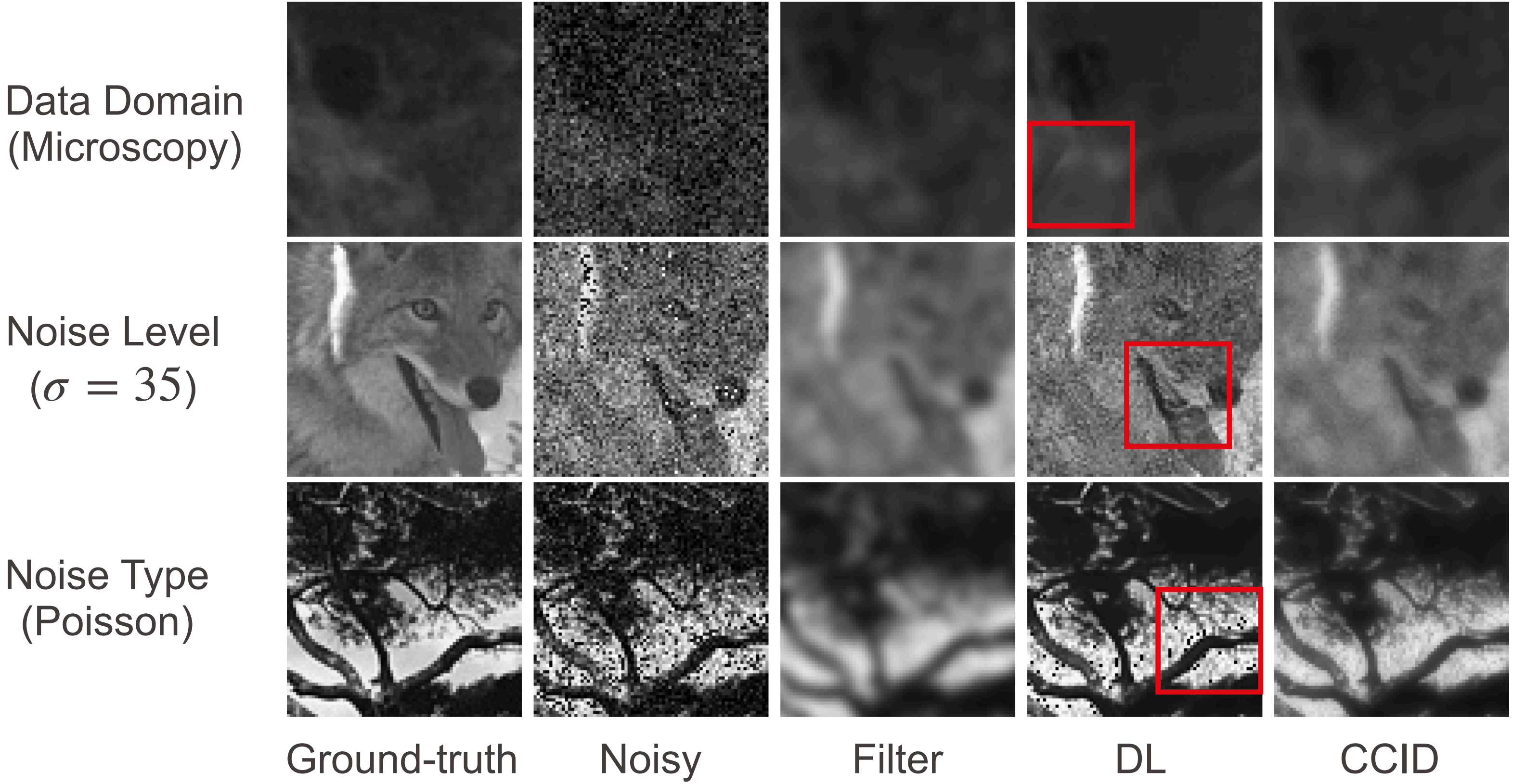
- User-understandable confidence prediction

Proposed Method
CCID1 Control

- Smooth fusion between:
  1. the image denoised with a reliable filter & 2. the deep denoised image
- Fusion in the frequency domain, controlled by a global parameter w

Filter $w = 0.2$ $w = 0.4$ $w = 0.6$ $w = 0.8$ Original

Proposed Method
CCID1 Generalization



Proposed Method
CCID | Generalization Cont'd

- We vary the data domain distribution, the noise level, and the type of noise in the test images → out-of-distribution (OOD) test data
- CCID$_d$ fixes a default invariable weight $w = 0.5$

OOD Type	Filter	DL	CCID$_d$	CCID
Data Domain	32.48/0.91	35.17/0.95	34.41/0.94	35.20/0.95
Noise Level	23.80/0.79	20.02/0.48	24.45/0.78	24.55/0.83
Noise Type	23.92/0.80	21.60/0.62	24.69/0.72	25.01/0.81

Average $PSNR/SSIM$ test results

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Key take-away messages

- Deep networks can hallucinate content from their rich priors. This content may be incorrect. To safeguard against this, CCID enables the user to control the addition of hallucination in the denoised result, through reliable fusion.

- We provide users with a confidence prediction revealing regions with likely deep denoiser errors.

- Our results outperform the deep denoiser and the reliable filter, especially when the test data diverge from the training data.

- Our CCID framework can be extended to further restoration tasks.

Thank you

Our **paper and code** are available on https://github.com/IVRL/CCID

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