

Variants of SURE-LET Approach to Image Denoising

Kao Kitichotkul

Department of Electrical Engineering, Stanford University

Motivation

- Many image denoisers assume priors; they perform poorly on images whose characteristics disagree with the priors.
- By using Stein's unbiased risk estimate (SURE), we can minimize the estimate of MSE without having to assume a prior [1]. In combination with the linear expansion of thresholds (LET) principle, denoising boils down to performing simple thresholding operations and solving a linear system of equations.



Left: Ground truth image.
Right: Denoising result from ADMM with TV prior of the left image corrupted by Gaussian noise. The result is Patchy due to sparse gradient Assumption of TV prior.



Related Work

- Blu and Luisier proposed the SURE-LET approach for Gaussian noise – the denoised results from thresholding in a transform domain are combined to minimize SURE [1].
- Li, Luisier, and Blu extends the SURE-LET approach to the Poisson and mixed Poisson-Gaussian noise cases [2].
- Anscombe proposed a method for approximating a Poisson distribution with a Gaussian distribution [3].

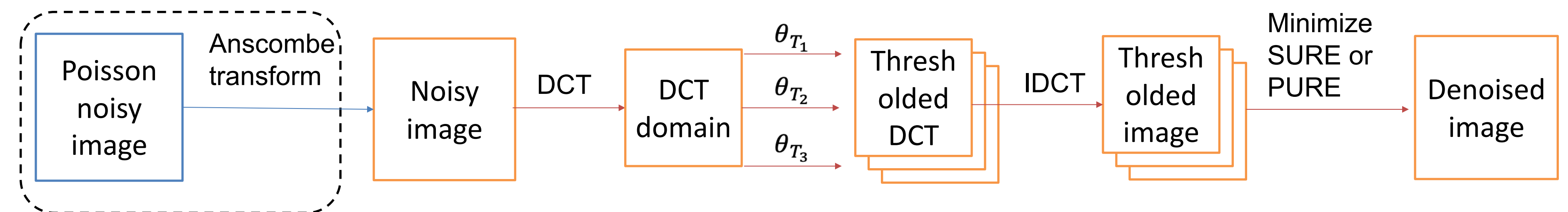
References

- [1] Blu and Luisier, "The SURE-LET Approach to Image Denoising," *IEEE Transactions on Image Processing*, 2007.
- [2] Li, Luisier, and Blu, "PURE-LET Image Deconvolution," *IEEE Transactions on Image Processing*, 2018.
- [3] Anscombe, "The Transformation of Poisson, Binomial and Negative-Binomial Data," *Biometrika*, 1948.

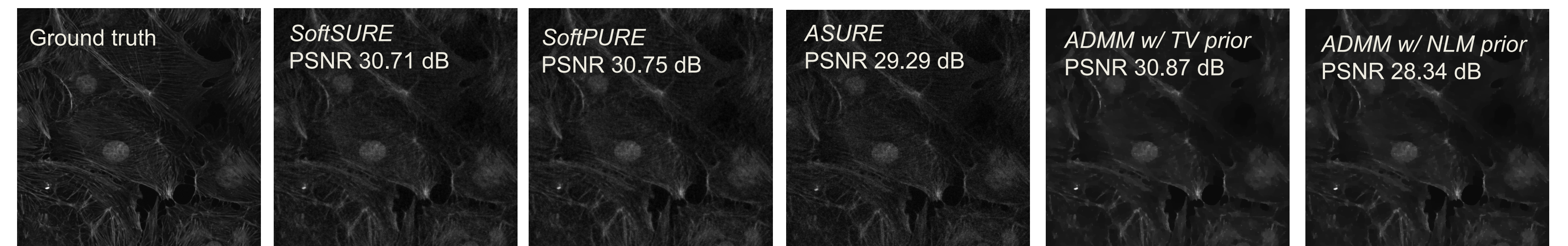
New Technique

- SoftSURE**: SURE-LET Gaussian denoiser using the soft threshold functions $\theta_T(\cdot)$ with a 3-4 values of thresholds T in the discrete cosine transform (DCT) domain. The standard deviation of the noise, which is required for the SURE-LET approach, is approximated by using a noise estimator.
- SoftPURE**: PURE-LET Poisson denoiser using the soft threshold functions like those in **SoftSURE** to minimize PURE, the MSE estimate for the Poissonian case. This denoiser requires the variance of the Poisson noise (the number of photons).
- ASURE**: SURE-LET Poisson denoiser applied to Anscombe-transformed image. The standard deviation of the noise in an Anscombe-transform image is always approximately 1. Hence, the noise estimator is not required in for this denoiser.

$$F(y) = \hat{x}$$
$$\text{SURE}(y) = \frac{\|F(y) - y\|^2}{N} + \frac{2\sigma^2}{N} \text{div}\{F(y)\} - \sigma^2$$
$$\text{LET} \quad F(y) = \sum_{k=1}^K a_k F_k(y)$$



Experimental Results



Two-photon image of bovine pulmonary artery endothelial (BPAE) cells from Zhang et al., "A Poisson-Gaussian Denoising Dataset with Real Fluorescence Microscopy Images," 2019. <https://arxiv.org/abs/1812.10366>. The ground truth was obtained by averaging 50 images taken with the same setting.

- PSNRs of the results from **SoftSURE**, **SoftPURE**, and **ASURE** are comparable to those from ADMM with TV prior and NLM prior. Note that we do not have a method to estimate Poisson noise variance σ^2 for **SoftPURE**, so we used the value $\sigma^2 = 50$.
- ADMM denoisers with TV prior and NLM prior yield overly smooth images, whereas our SURE-LET approaches preserve more details in the darker regions.