A Trainable Bounded Denoiser Using Double Tight Frame Network For Snapshot Compressive Imaging

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Introduction

Recently, the plug-and-play (PnP) SCI algorithms using deep Gaussian denoisers have achieved remarkable reconstructions, and their convergences have been proven based on the assumption of bounded denoisers. However, most of deep Gaussian denoisers are difficult to be proven as bounded denoisers due to the complicated deep network architectures.

Contributions

- A novel supervised tight frame learning framework.
- A deep shrinkage network (DSN) for filtering the frame coefficients adaptively.
- An effective and trainable bounded denoiser, termed as DoubleTFCnet.
- A novel PnP SCI algorithm using DoubleTFCnet, termed as PnP-DoubleTFCnet.

Work Flow

Single Tight Frame

$$\hat{x}_s = W^{T} T_{\varepsilon}(Wx)$$

$$\mathcal{L} = \|x - \hat{x}_s\|_2^2 + \lambda \|W^{T}W - I\|_F^2$$

W represents a tight frame.

Double Tight Frames

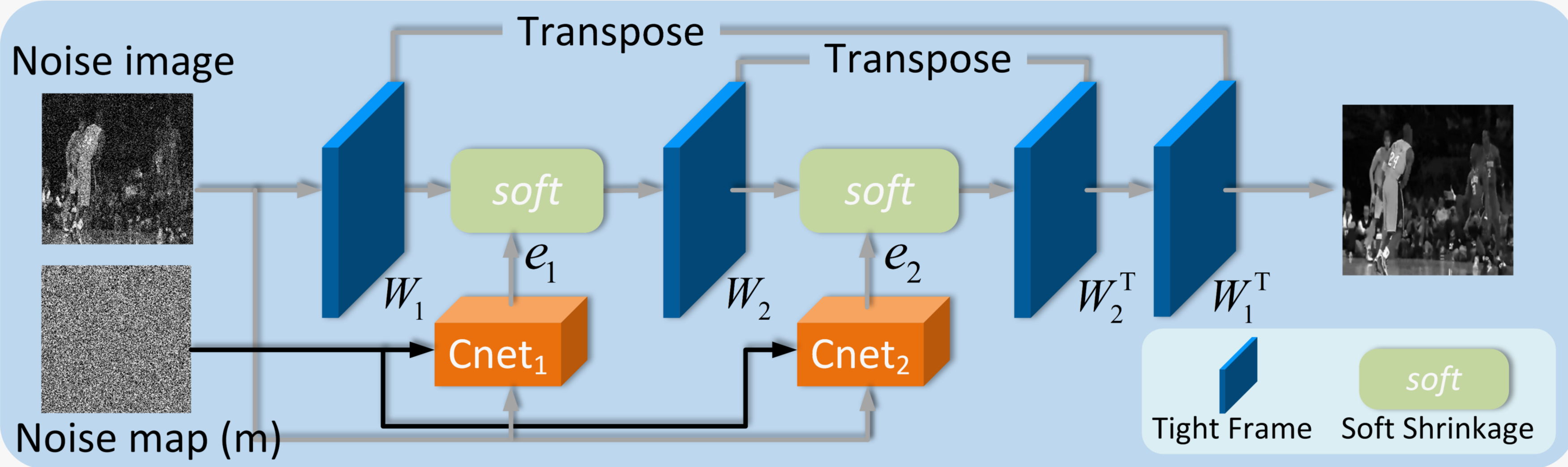
$$\hat{x}_d = W_1^{T} W_2^{T} T_{\varepsilon_2}\left[W_2 T_{\varepsilon_1}(W_1 x)\right]$$

$$\mathcal{L} = \|x - \hat{x}_d\|_2^2 + \sum_{i=1}^{2} \lambda_i \|W_i^{T}W_i - I\|_F^2$$

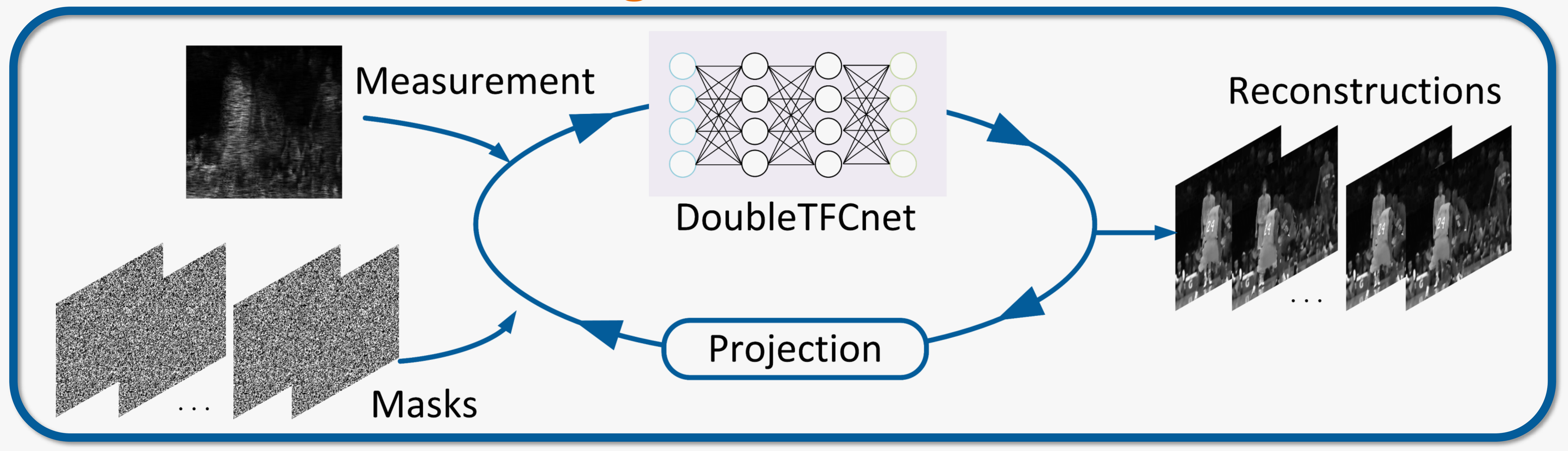
$T_{\varepsilon}(\cdot)$ is the soft threshold function.

- The thresholds of the DSN: $e_i = \mathrm{Cnet}_i(x) \odot m$
- The DoubleTFCnet: $\mathcal{D}(x) = W_1^{T} W_2^{T} T\left[W_2 T(W_1 x, e_1), e_2\right]$

The architecture of the DoubleTFCnet denoiser

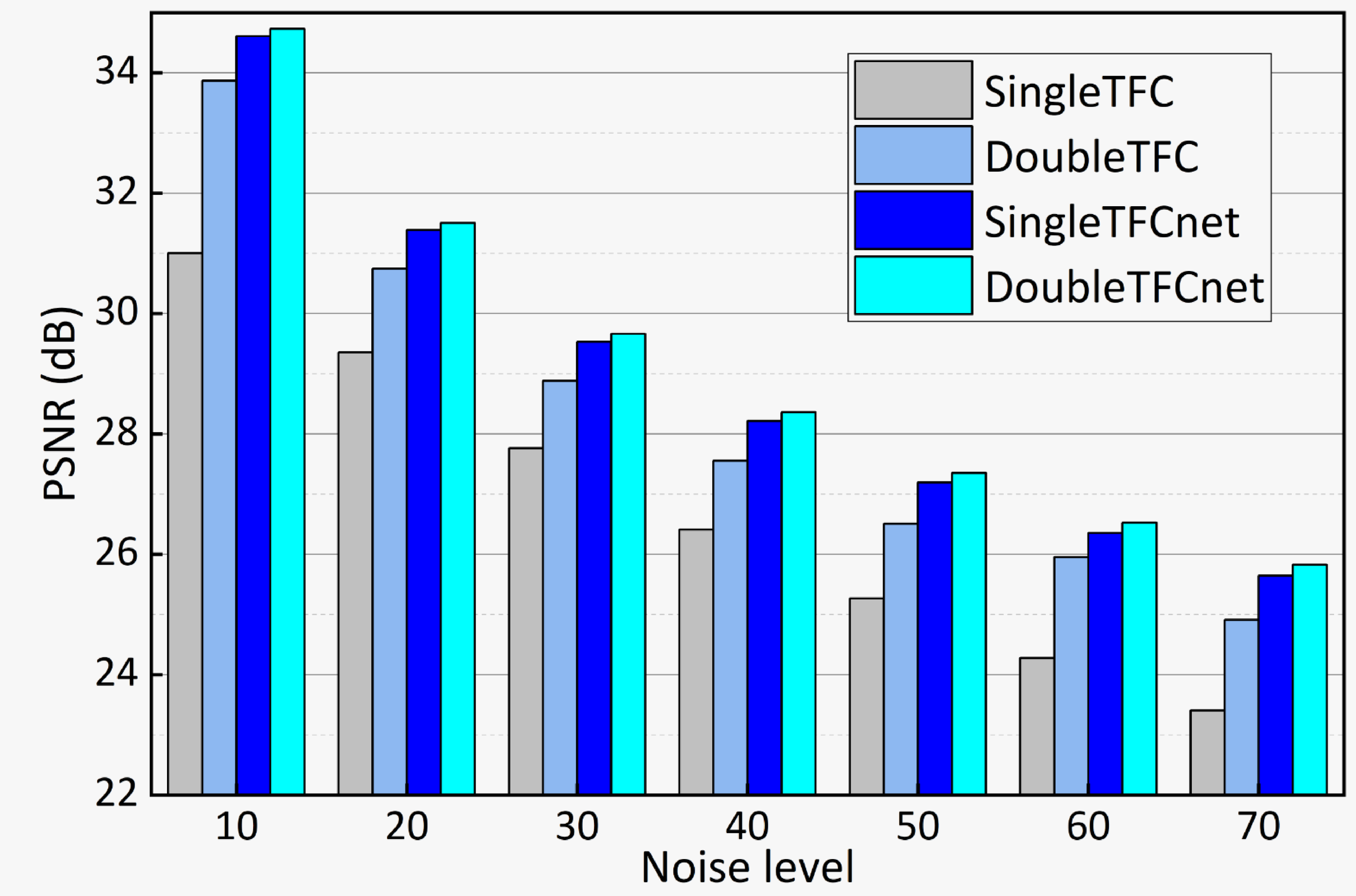


The schematic diagram of the PnP-DoubleTFCnet



Denoising Task

The average PSNR values of four models on Set12



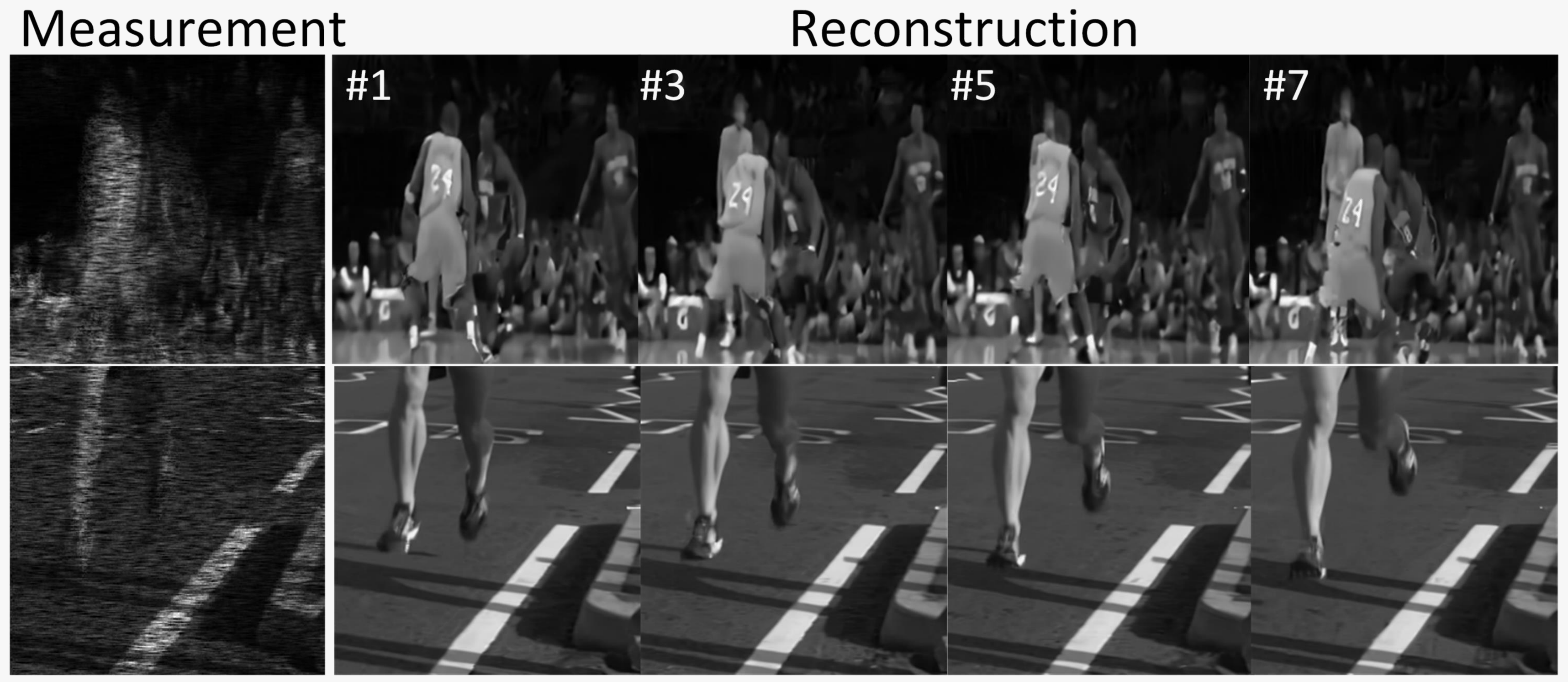
The average PSNR values of different denoisers on BSD68

Denoiser	$\sigma=5$	$\sigma=10$	$\sigma=20$	$\sigma=30$	$\sigma=40$	$\sigma=50$
BM3D	37.54	33.33	29.66	27.78	26.57	25.69
DnCNN	37.74	33.73	30.18	28.32	27.09	26.19
FFDNet	37.73	33.74	30.23	28.40	27.20	26.32
DoubleTFCnet	37.84	33.79	30.25	28.39	27.17	26.28

Snapshot Compressive Imaging Task

The average PSNR and SSIM values achieved by different SCI algorithms on simulated benchmark datasets

Algorithm	PSNR	SSIM
GAP-TV	26.94	0.8332
E2E-CNN	29.26	0.8999
PnP-FFDNet	29.21	0.8876
PnP-DoubleTFCnet	29.86	0.8960



Conclusions

- The denoisers using the double tight frames have better denoising ability than those using the single one, the denoisers equipped with Cnet can achieve higher PSNR values compared with the denoisers without Cnet.
- The proposed DoubleTFCnet is a provable bounded denoiser, and can achieve denoising ability on-par with the existing Gaussian denoisers.
- The proposed PnP-DoubleTFCnet algorithm can achieve competitive reconstruction results compared with benchmark SCI algorithms.

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