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DiffSCI: Zero-Shot Snapshot Compressive Imaging via Iterative Spectral Diffusion Model

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Outline

- Introduction
- Proposed Network
- Experimental Results

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Snapshot Compressive Imaging(SCI)

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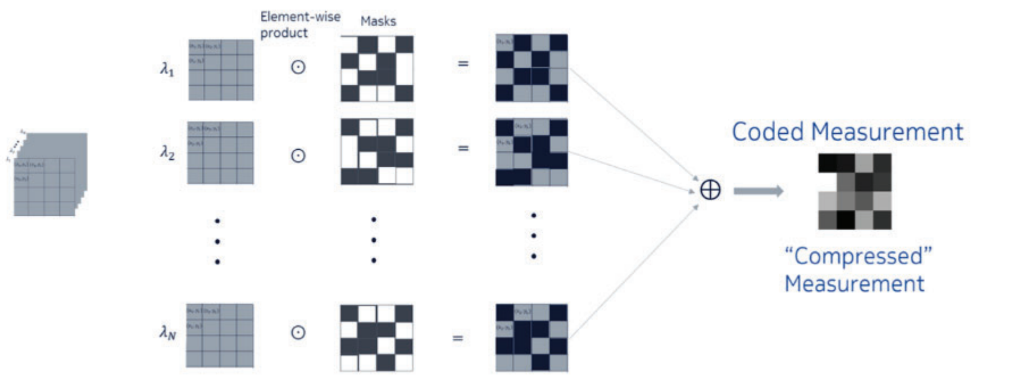

Figure 1. Encoding process of SCI.

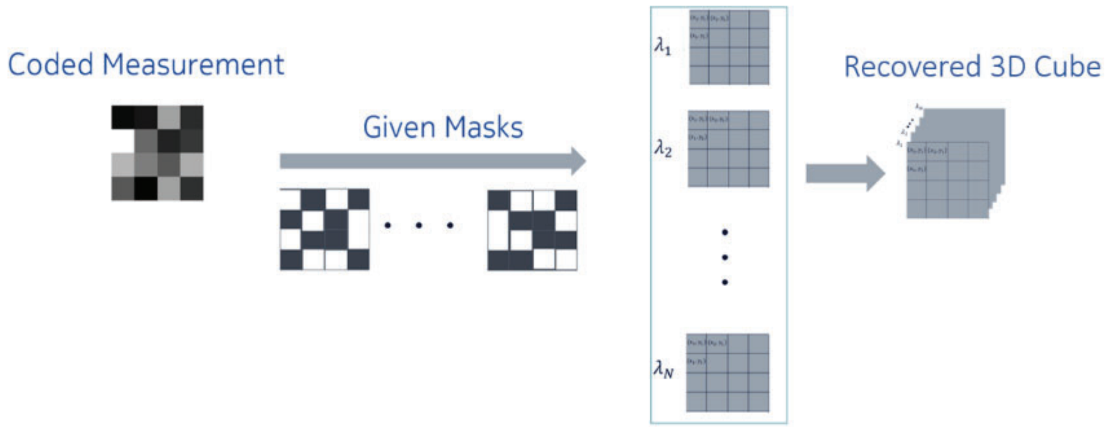

Figure 2. Decoding process of SCI.

X. Yuan, D. J. Brady and A. K. Katsaggelos, "Snapshot Compressive Imaging: Theory, Algorithms, and Applications," in IEEE Signal Processing Magazine, vol. 38, no. 2, pp. 65-88, March 2021, doi: 10.1109/MSP.2020.3023869

Coded Aperture Snapshot Spectral Imaging (CASSI) System

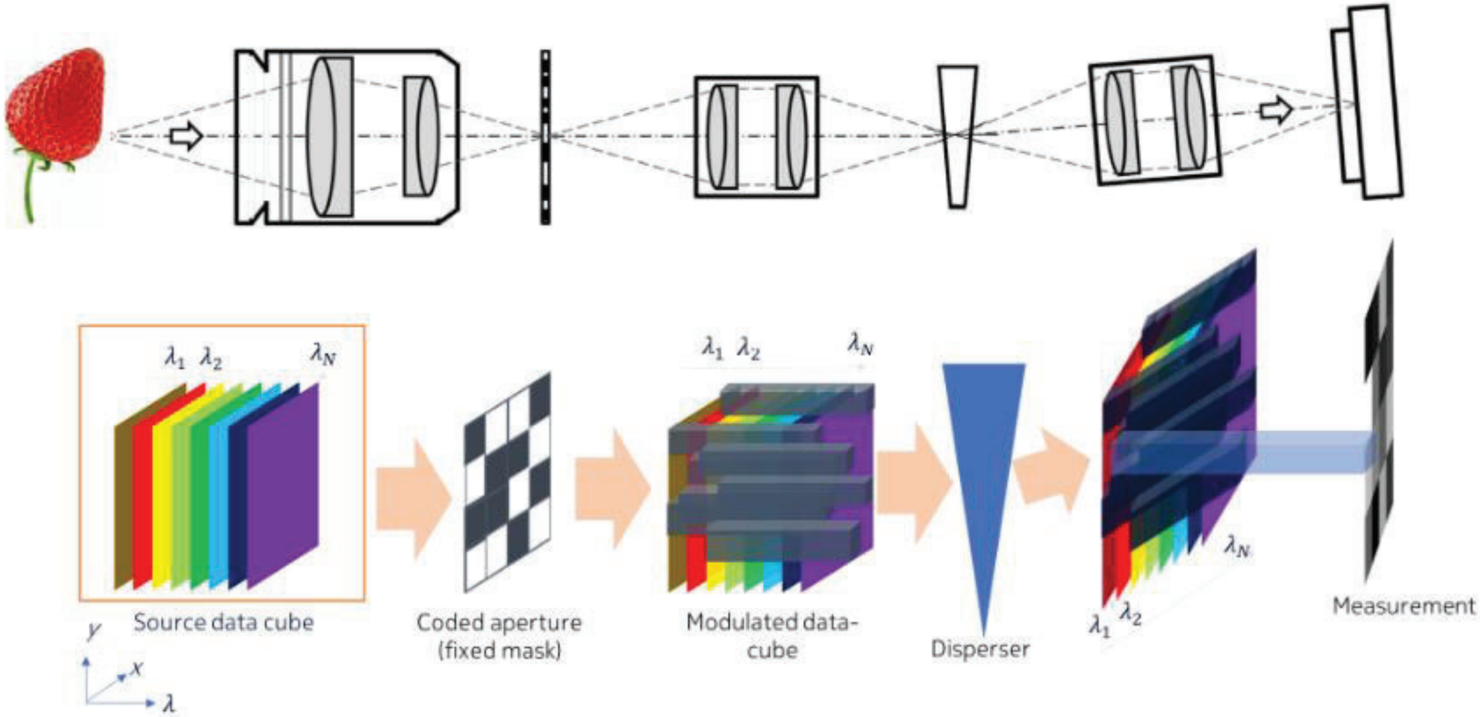

Figure 3. Schematic (top row) and sampling principle (bottom row) of the coded aperture snapshot spectral imaging (CASSI) system

X. Yuan, D. J. Brady and A. K. Katsaggelos, "Snapshot Compressive Imaging: Theory, Algorithms, and Applications," in IEEE Signal Processing Magazine, vol. 38, no. 2, pp. 65-88, March 2021, doi: 10.1109/MSP.2020.3023869

Current Frameworks of the Reconstruction Algorithm for SCI

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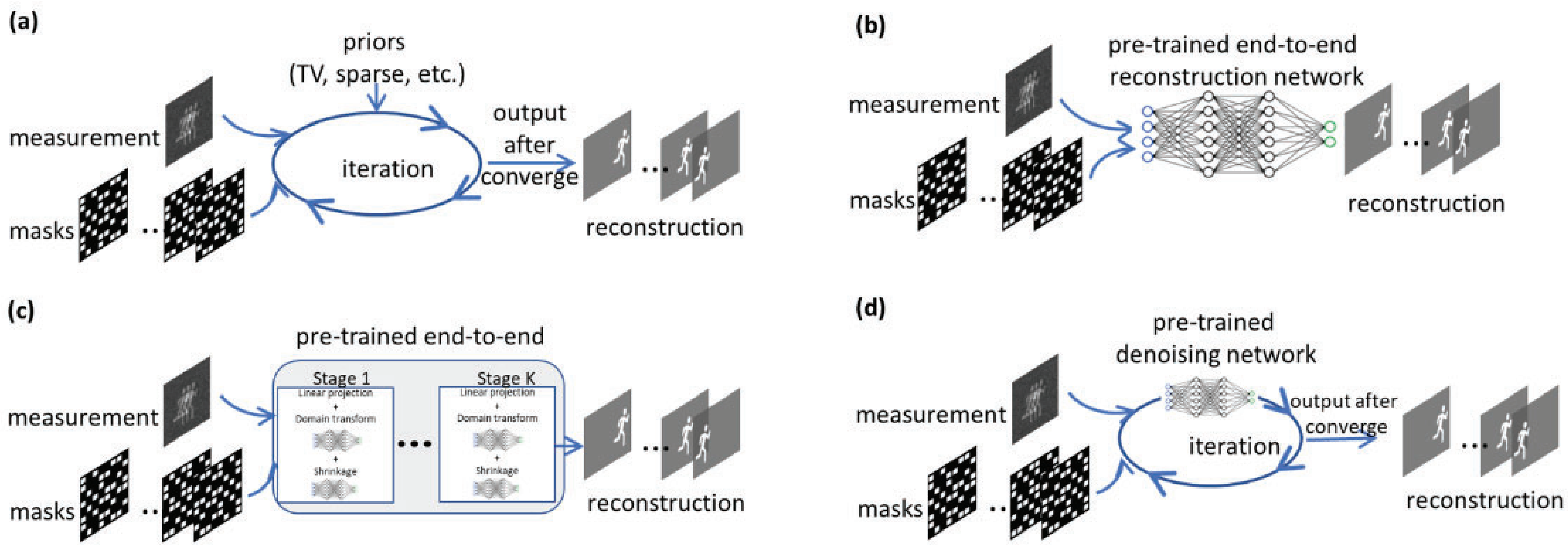

Figure 4. Different frameworks of the reconstruction algorithm for SCI: (a) Conventional optimization based iterative algorithm. (b) End-to-end deep learning based on convolutional neural networks, (c) deep unrolling/unfolding algorithms, where K small CNNs are used and (d) Plug-and-Play algorithms using pre-trained denoising network as priors.

X. Yuan, D. J. Brady and A. K. Katsaggelos, "Snapshot Compressive Imaging: Theory, Algorithms, and Applications," in IEEE Signal Processing Magazine, vol. 38, no. 2, pp. 65-88, March 2021, doi: 10.1109/MSP.2020.3023869

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Proposed Network

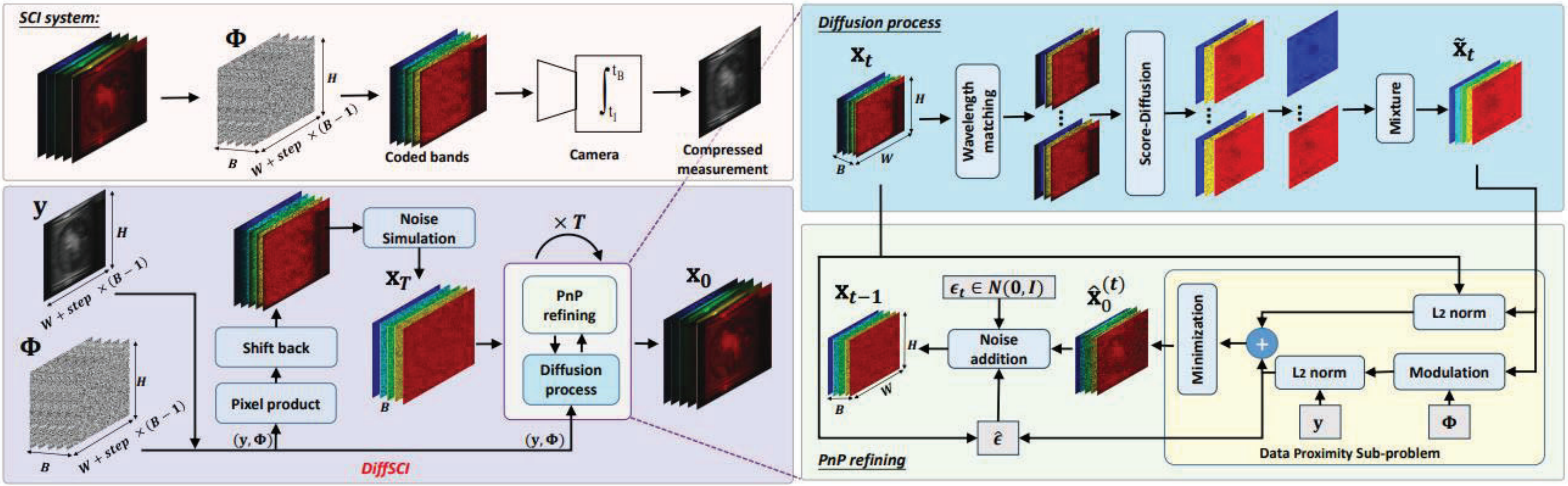


Figure 5. Architecture of the proposed DiffSCI network

Proposed Network

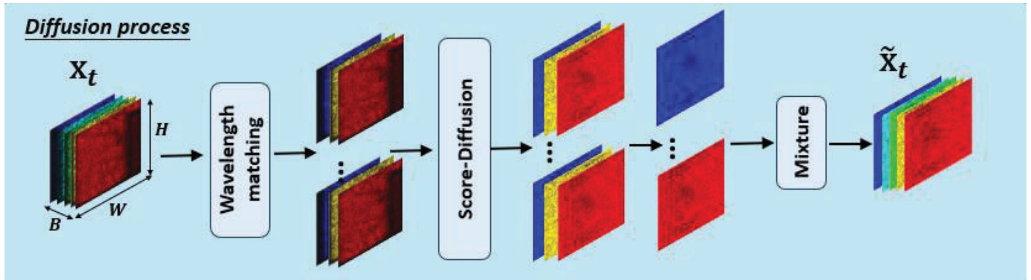


Figure 6. Integrating diffusion model with WM method

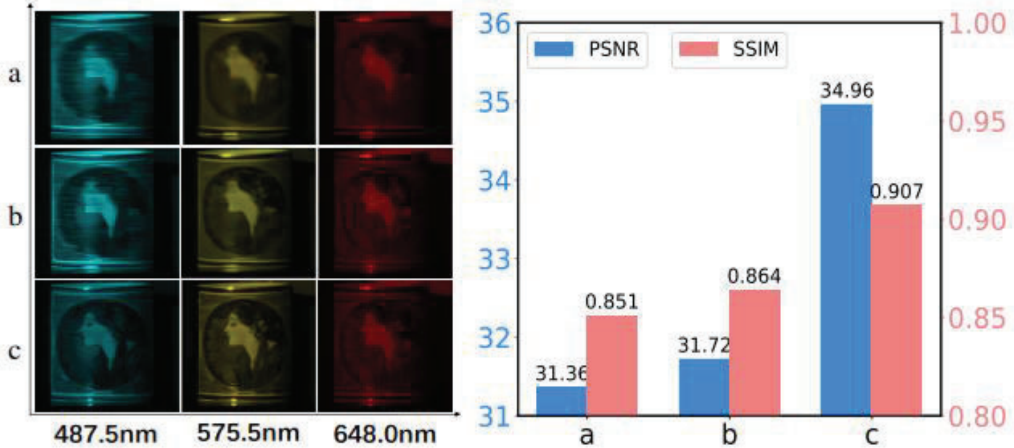


Figure 7. Visual effects and PSNR/SSIM presentation of (a) independently selecting non-overlapping bands method, (b) spectral correlation modeling, and (c) wavelength matching method

independently selecting non-overlapping bands method

$$C_k = [B_{i-1}, B_i, B_{i+1}],\ \ C_{k+1} = [B_{i+2}, B_{i+3}, B_{i+4}]$$

$$C'_k = [B'_{i-1}, B'_i, B'_{i+1}],\ \ C'_{k+1} = [B'_{i+2}, B'_{i+3}, B'_{i+4}]$$

spectral correlation modeling

$$C_i = [B_{i-1}, B_i, B_{i+1}],\ \ C_{i+1} = [B_i, B_{i+1}, B_{i+2}]$$

$$C'_i = B'_i, \qquad C'_{i+1} = B'_{i+1}$$

Wavelength matching (WM):

$$C_i = [B_i, B_{i+m}, B_{i+n}]$$

$$C'_i = B'_i$$

Proposed Network

Algorithm 1 DiffSCI sampling

Require: $\mathbf{s}_\theta, T, B, \mathbf{y}, \mathbf{\Phi}, \sigma_n, \{\bar{\sigma}_t\}_{t=1}^{T}, \zeta, \lambda$

Initialize $\mathbf{x}_T \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$, $\mathbf{y}_1 = 0$, pre-calculate $\rho_t \triangleq \lambda\sigma_n^2/\bar{\sigma}_t^2$.

for $t = T$ **to** 1 **do**

  for $b = 1$ **to** B **do**

    $\mathbf{x}_t^{(b)} = \mathrm{WM}(\mathbf{B}_b)$ *// wavelength mathcing method*

    $\tilde{\mathbf{x}}_t^{(b)} = \frac{1}{\sqrt{\bar{\alpha}_t}}(\mathbf{x}_t^{(b)} + (1-\bar{\alpha}_t)\mathbf{s}_\theta(\mathbf{x}_t^{(b)}, t))$ *//predict clean image from* $\mathbf{x}_t^{(b)}$ *with score based model*

  end for

  Get $\tilde{\mathbf{x}}_t$ *// combination*

  $\mathbf{y}_1 = \mathbf{y}_1 + (\mathbf{y} - \mathbf{\Phi}\tilde{\mathbf{x}}_t)$ *// calculate and accumulate residuals*

  $\hat{\mathbf{x}}_0^{(t)} = \tilde{\mathbf{x}}_t + sc \cdot \mathbf{\Phi}^T(\mathbf{y}_1 - \mathbf{\Phi}\tilde{\mathbf{x}}_t) \oslash [Diag(\mathbf{\Phi}\mathbf{\Phi}^T) + \rho_t]$ *// acceleration for data subproblem*

  $\hat{\epsilon} = \frac{1}{\sqrt{1-\bar{\alpha}_t}}(\mathbf{x}_t - \sqrt{\bar{\alpha}_t}\hat{\mathbf{x}}_0^{(t)})$

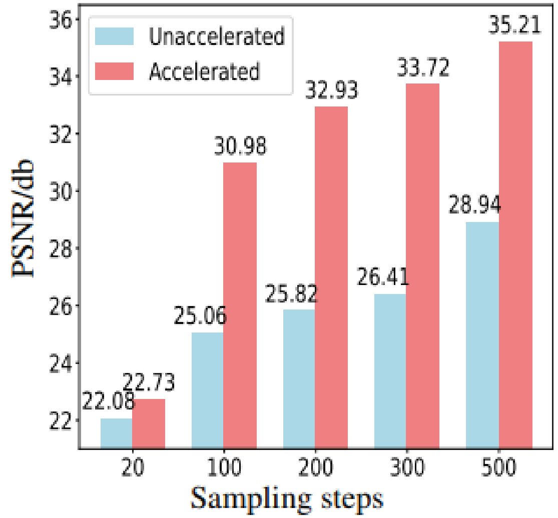
  $\epsilon_t \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$

  $\mathbf{x}_{t-1} = \sqrt{\bar{\alpha}_{t-1}}\hat{\mathbf{x}}_0^{(t)} + \sqrt{1-\bar{\alpha}_{t-1}}(\sqrt{1-\zeta}\hat{\epsilon} + \sqrt{\zeta}\epsilon_t)$ *// diffusion to* $\mathbf{x}_{t-1}$ *to finish one step sampling*

end for

return $\mathbf{x}_0$

Figure 8. DiffSCI sampling



time(s)	unaccelerated	accelerated
20	31.04	30.36 0.68↑
100	128.03	130.15 2.12↓
200	250.83	251.98 1.12↓
300	395.69	372.77 22.92↑
500	899.20	721.50 177.71↑

steps

Time of each step

Figure 9. Effect of sampling steps and acceleration algorithm on PSNR and time.

$$x_{k+1} = z_k + \Phi^T[y_1 - \Phi z_k] \oslash [\mathrm{Diag}(\Phi\Phi^{\mathrm{T}}) + \mu]$$
$$= z_k + \Phi^T[\sum_{i=1}^{k}(y - \Phi z_k) - \Phi z_k] \oslash [\mathrm{Diag}(\Phi\Phi^{\mathrm{T}}) + \mu]$$

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Results on Simulation Datasets

Table 1. Comparisons between DiffSCI and SOTA methods on 10 simulation scenes (S1~S10). Category, PSNR (upper entry in each cell), and SSIM (lower entry in each cell) are reported. The best and second best results are highlighted in bold and underlined, respectively.

Algorithms	Category	Reference	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Avg
TwIST [3]	Model	TIP 2007	25.16 0.700	23.02 0.604	21.40 0.711	30.19 0.851	21.41 0.635	20.95 0.644	22.20 0.643	21.82 0.650	22.42 0.690	22.67 0.569	23.12 0.669
GAP-TV [53]	Model	ICIP 2016	26.04 0.817	21.66 0.724	24.86 0.732	30.51 0.875	24.33 0.778	25.11 0.790	18.28 0.730	23.94 0.780	21.77 0.732	23.08 0.721	23.96 0.768
DeSCI [28]	Model	TPAMI 2019	28.38 0.803	26.00 0.701	23.11 0.730	28.26 0.855	25.41 0.778	24.66 0.764	24.96 0.725	24.15 0.747	23.56 0.701	24.17 0.677	25.27 0.748
λ-Net [39]	CNN (Supervised)	ICCV 2019	30.10 0.849	28.49 0.805	27.73 0.870	37.01 0.934	26.19 0.817	28.64 0.853	26.47 0.806	26.09 0.831	27.50 0.826	27.13 0.816	28.53 0.841
TSA-Net [35]	CNN (Supervised)	ECCV 2020	32.31 0.894	31.03 0.863	32.15 0.916	37.95 0.958	29.47 0.884	31.06 0.902	30.02 0.880	29.22 0.886	31.14 0.909	29.18 0.861	31.35 0.895
HDNet [23]	Transformer (Supervised)	CVPR 2022	34.96 0.937	35.64 0.943	35.55 0.946	41.64 0.976	32.56 0.948	34.33 0.954	33.27 0.928	32.26 0.945	34.17 0.944	32.22 0.940	34.66 0.946
MST-L [5]	Transformer (Supervised)	CVPR 2022	35.30 0.944	36.13 0.948	35.66 0.954	40.05 0.976	32.84 0.949	34.56 0.955	33.80 0.930	32.74 0.950	34.37 0.944	32.63 0.943	34.81 0.949
MST++ [7]	Transformer (Supervised)	CVPR 2022	35.57 0.945	36.22 0.949	37.00 0.959	**42.86** 0.980	33.27 0.954	35.27 0.960	34.05 0.936	33.50 0.956	36.17 0.956	**33.26** 0.949	**35.72** 0.955
CST-L+ [6]	Transformer (Supervised)	ECCV 2022	**35.64** **0.951**	**36.79** **0.957**	37.71 **0.965**	41.38 **0.981**	32.95 **0.957**	**35.58** **0.966**	34.54 **0.947**	**34.07** **0.964**	35.62 **0.959**	32.82 **0.949**	35.71 **0.960**
DGSMP [24]	Deep Unfolding (Supervised)	CVPR 2021	33.26 0.915	32.09 0.898	33.06 0.925	40.54 0.964	28.86 0.882	33.08 0.937	30.74 0.886	31.55 0.923	31.66 0.911	31.44 0.925	32.63 0.917
ADMM-Net [32]	Deep Unfolding (Supervised)	ICCV 2019	34.03 0.919	33.57 0.904	34.82 0.933	39.46 0.971	31.83 0.924	32.47 0.926	32.01 0.898	30.49 0.907	33.38 0.917	30.55 0.899	33.26 0.920
GAP-Net [38]	Deep Unfolding (Supervised)	IJCV 2023	33.63 0.913	33.19 0.902	33.96 0.931	39.14 0.971	31.44 0.921	32.29 0.927	31.79 0.903	30.25 0.907	33.06 0.916	30.14 0.898	32.89 0.919
PnP-CASSI [58]	PnP (Zero-Shot)	PR 2021	29.09 0.799	28.05 0.708	30.15 0.850	39.17 0.939	27.45 0.798	26.16 0.752	26.92 0.736	24.92 0.710	27.99 0.752	25.58 0.664	28.55 0.771
DIP-HSI [37]	PnP (Zero-Shot)	ICCV 2021	31.32 0.855	25.89 0.699	29.91 0.839	38.69 0.926	27.45 0.796	29.53 0.824	27.46 0.700	27.69 0.802	33.46 0.863	26.10 0.733	29.75 0.803
HLRTF [31]	Tensor Network (Self-Supervised)	CVPR 2022	29.04 0.794	26.24 0.679	27.91 0.862	38.93 0.962	25.33 0.760	24.80 0.735	25.54 0.766	23.78 0.733	30.04 0.848	24.91 0.660	27.65 0.780
DiffSCI	PnP-Diffusion (Zero-Shot)	Ours	34.96 0.907	34.60 0.905	**39.83** 0.949	42.65 0.951	**35.21** 0.946	33.12 0.917	**36.29** 0.944	30.42 0.887	**37.27** 0.931	28.49 0.821	35.28 0.916

Results on Simulation Datasets

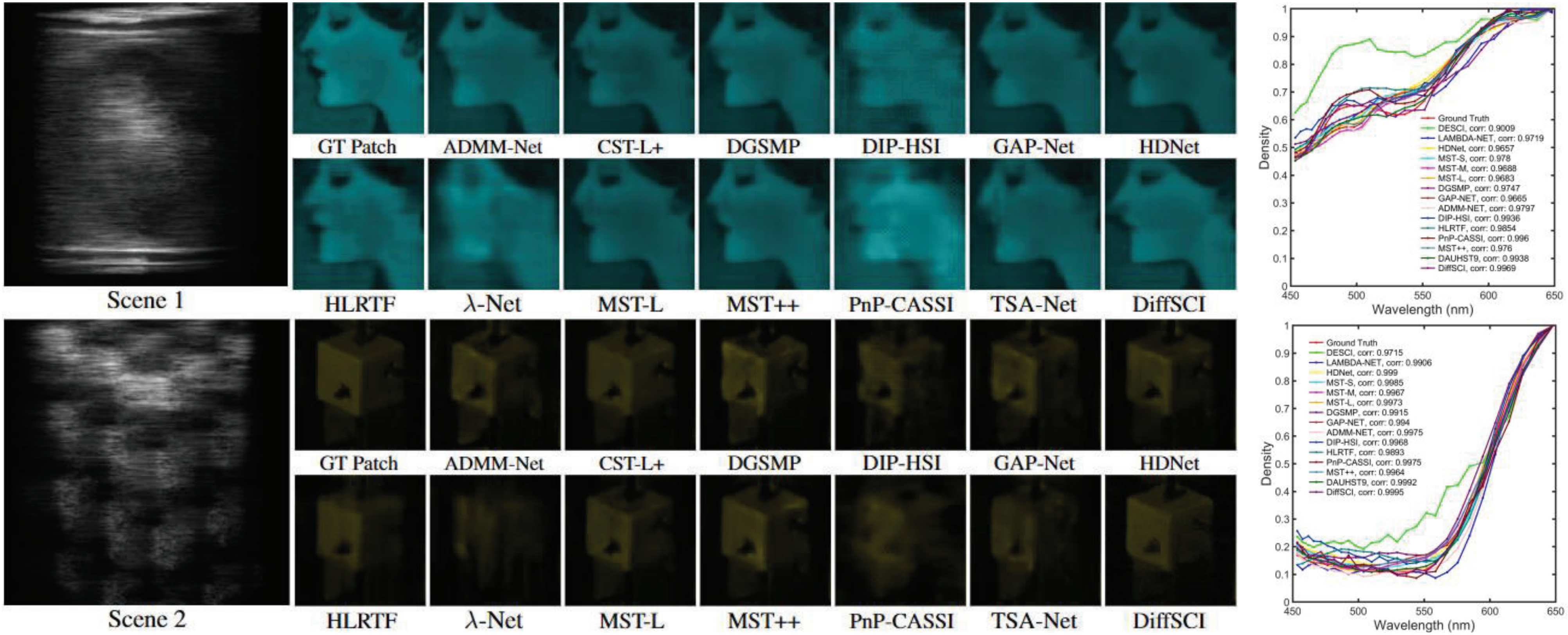

Figure 10. Visual comparison and Spectral Density Curves on simulation dataset.

Results on Real Datasets

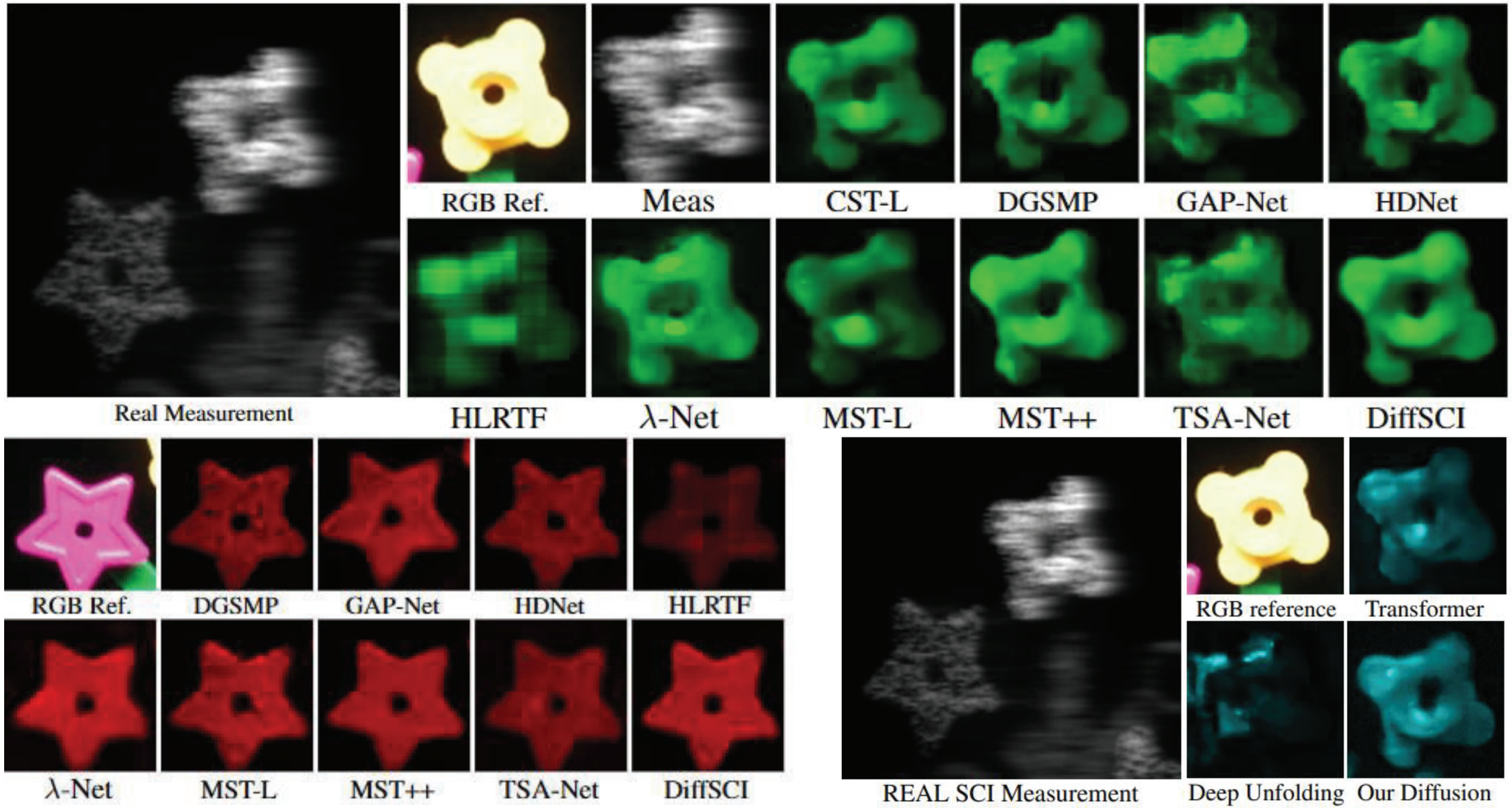

Figure 11. Visual comparison on real dataset.

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Thank You for Your Attention!