

4D Hyperspectral Photoacoustic Data Restoration with Reliability Analysis: Supplementary Materials

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1. Abstract

In the supplementary materials, we will provide the visualization of the entire HSPA dataset, as we mentioned in section 5.1 in the main submission. We also compare the full error metrics for reference data, as we mentioned in section 5.2. Finally, we will show the visualization for restoration results on 'Tube' and 'Banana', as well as extra experiment results on other portions of 'Hand', as we mentioned in section 5.3.1.

2. HSPA data visualization

Our 4D HSPA dataset includes 'Leaf', 'Tube', and 'Banana'. For Leaf and Banana, we uniformly measured 9 bands ranging from 420 nm to 580 nm. For Tube, we uniformly measured 11 bands ranging from 500 nm to 700 nm. The entire HSPA data are shown in Figs. 1, 2, and 3.

3. Error metrics for reference data

We examined the validity of noise-removed full-grid reference data by capturing an opaque plane with five different orientations. We calculated the sum of squares errors (SSE) of the points on the plane for each orientation:

$$\begin{aligned} SSE_{noisy} &= \sum_{x,y} (z_n - z_{gt})^2, \\ SSE_{ref} &= \sum_{x,y} (z_r - z_{gt})^2, \end{aligned} \tag{1}$$

where $(x, y, z)_{gt}$ is the ground-truth surface locations, $(x, y, z)_n$ and $(x, y, z)_r$ are the locations of maximum intensity points from the noisy observation and our reference data, respectively. The comparison of SSE results are given in Table 1.

Table 1. SSE comparison for noisy and reference data.

plane equation	inclination	SSE_{noisy}	SSE_{ref}
$0.59x + 0.13y + 0.02 = z$	39.12°	75.02	1.11
$0.84x + 0.12y + 0.02 = z$	50.93°	172.10	3.13
$0.76x + 0.19y + 0.01 = z$	47.73°	241.01	5.57
$0.44x + 0.06y + 0.01 = z$	29.53°	95.32	1.40
$0.68x + 0.05y + 0.01 = z$	43.10°	141.26	2.40

4. Extra experiment results

We visualize the restoration results of 'Tube' and 'Banana' in Fig. 4. We further evaluate the restoration quality on other portions of 'Hand' data. The visualization of restoration results are shown in Fig. 5. The comparison of quantitative metrics (PSNR and SSIM) for different methods are listed in Table 2.

In addition, we provide 3D visualization of the original data and restoration results in the supplemental video.

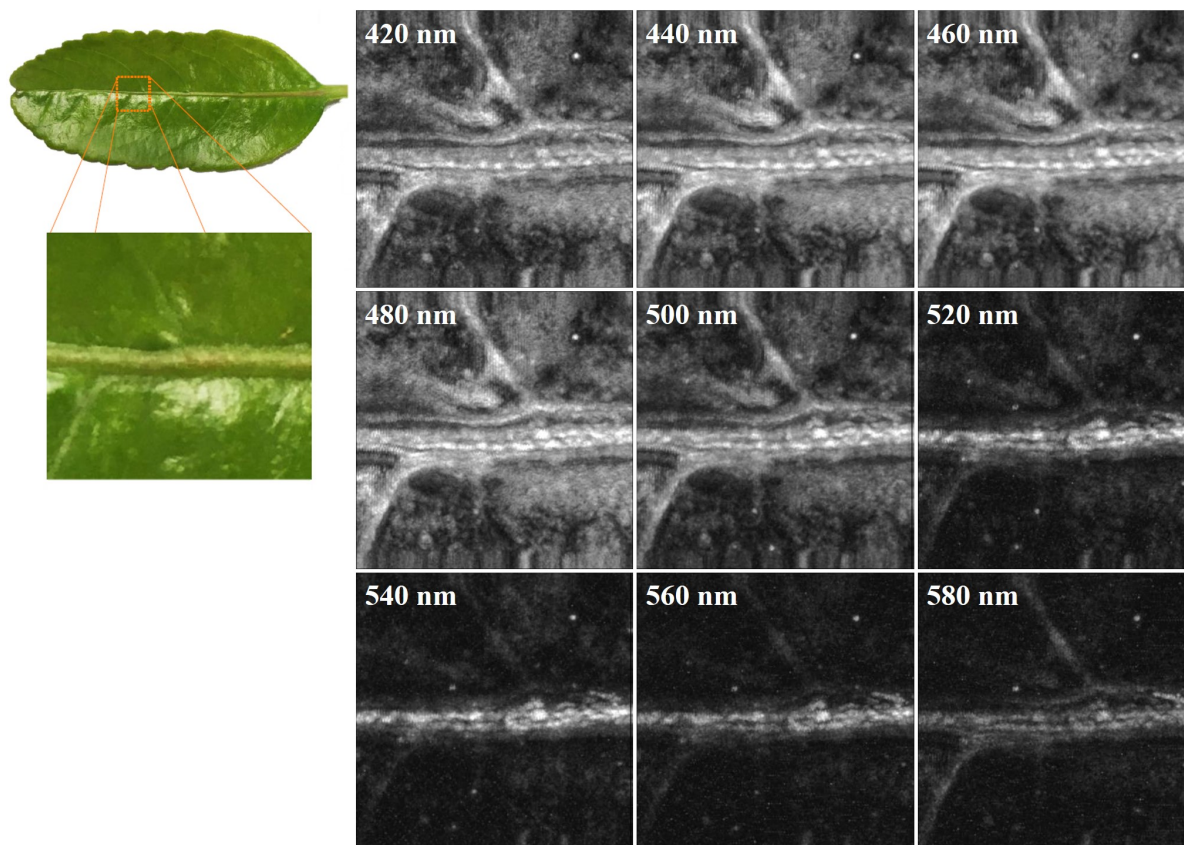


Figure 1. The visualization of Leaf data for each spectral band.

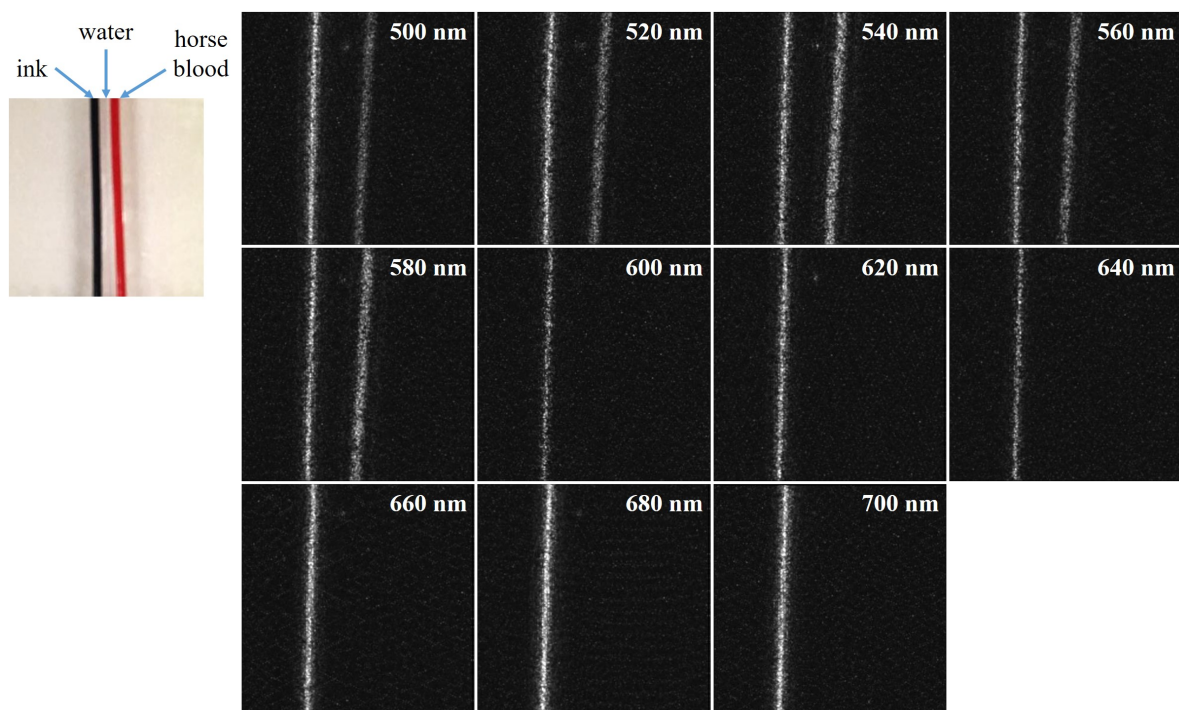


Figure 2. The visualization of Tube data for each spectral band.

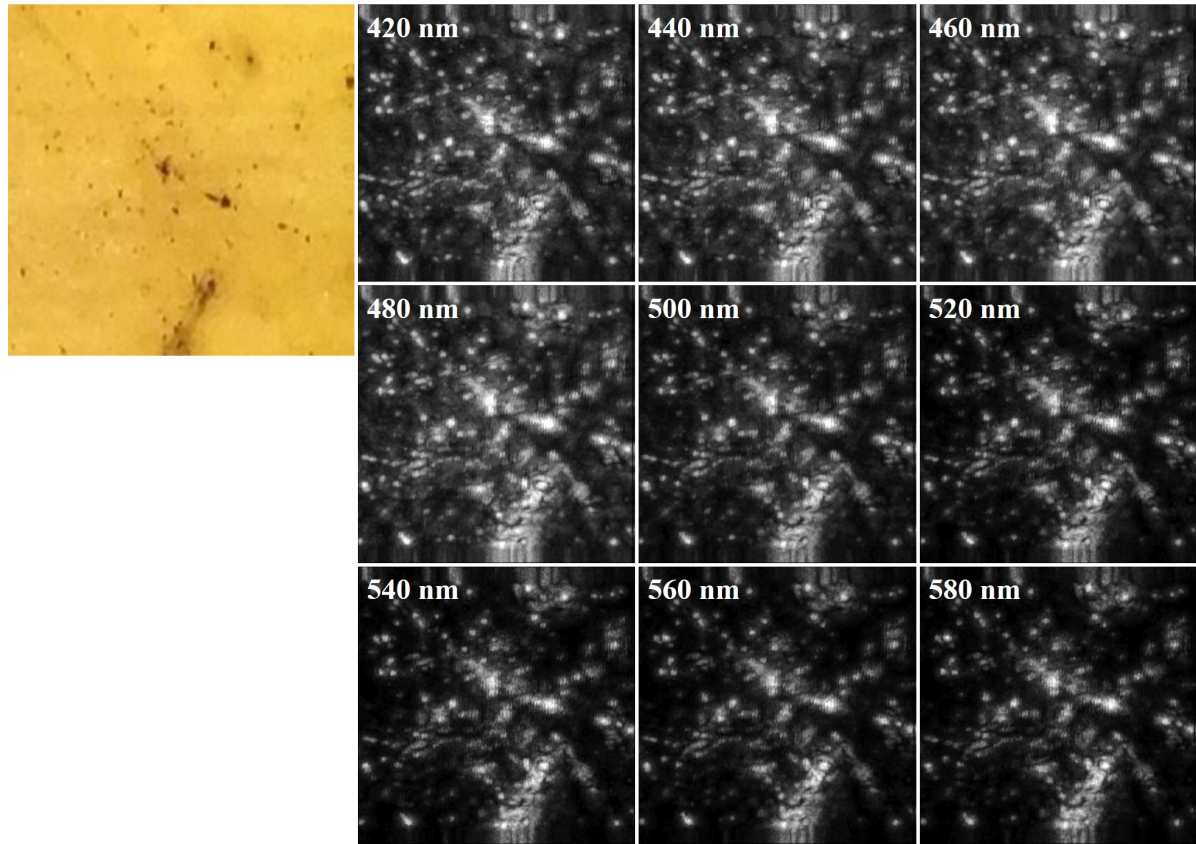


Figure 3. The visualization of Banana data for each spectral band.

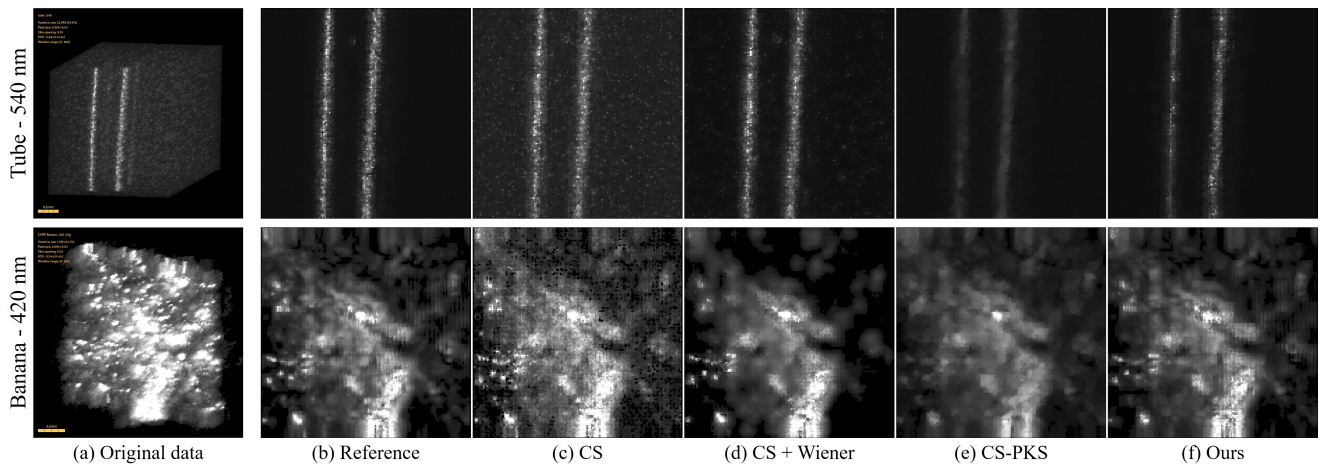


Figure 4. The visualization of restoration results by different methods on 50% sampled data (Tube and Banana).

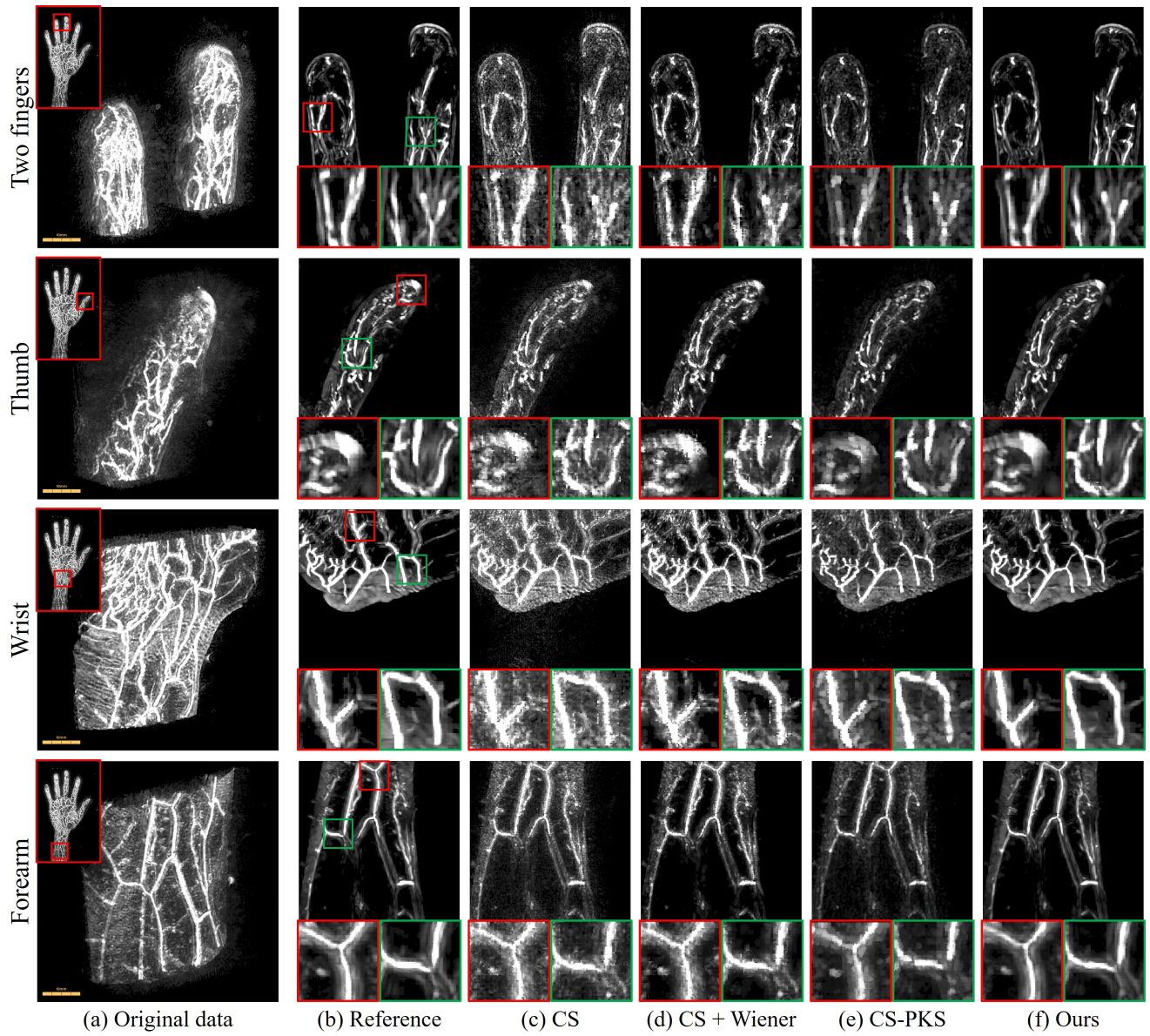


Figure 5. The visualization of restoration results by different methods on 50% sampled data (different portions of Hand).

Table 2. The quantitative results for different methods

Sample Ratio	Method	Two fingers		Thumb		Wrist		Forearm	
		PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
0.7	default CS	38.91	0.2341	39.07	0.1917	36.78	0.3570	36.39	0.2523
	CS + Wiener	41.18	0.2604	41.62	0.2169	39.70	0.4226	39.25	0.2885
	CS + BM4D	42.19	0.2764	42.08	0.2213	40.17	0.4372	39.36	0.2935
	CS-PKS	41.30	0.2706	42.20	0.2273	39.46	0.4347	39.50	0.2981
	SMF-LRTC	39.35	0.2387	39.45	0.1948	37.10	0.3595	36.76	0.2566
	Ours w/o reliab.	44.52	0.3173	45.80	0.2801	42.87	0.5096	44.82	0.4238
	Ours w/ reliab.	54.58	0.9518	57.98	0.9652	53.26	0.9681	55.58	0.9806
0.5	default CS	38.79	0.2295	39.29	0.1886	36.70	0.3550	36.53	0.2495
	CS + Wiener	40.63	0.2566	41.57	0.2143	39.07	0.4212	39.03	0.2859
	CS + BM4D	41.85	0.2804	42.32	0.2236	39.85	0.4438	39.61	0.2988
	CS-PKS	40.47	0.2601	42.03	0.2198	38.76	0.4272	39.32	0.2938
	SMF-LRTC	39.78	0.2409	39.97	0.1966	37.44	0.3613	37.27	0.2591
	Ours w/o reliab.	44.20	0.3263	46.04	0.2860	42.84	0.5269	44.83	0.4591
	Ours w/ reliab.	47.93	0.8267	51.07	0.8798	46.62	0.8911	48.48	0.9275
0.3	default CS	37.78	0.2050	39.01	0.1693	35.74	0.3283	36.09	0.2278
	CS + Wiener	38.95	0.2342	40.68	0.1953	37.15	0.3953	37.82	0.2630
	CS + BM4D	39.79	0.2657	41.39	0.2113	37.83	0.4233	38.57	0.2864
	CS-PKS	38.16	0.2029	40.36	0.1732	36.27	0.3389	37.49	0.2409
	SMF-LRTC	40.02	0.2392	40.53	0.1959	37.55	0.3555	37.74	0.2587
	Ours w/o reliab.	41.86	0.3336	44.47	0.2853	40.27	0.5351	42.33	0.5254
	Ours w/ reliab.	42.26	0.5794	45.05	0.7108	40.49	0.6881	42.29	0.7767