Supplementary Material
MFmamba: A Multi-function Network for Spatial and Spectral Resolution of Panchromatic Image Using State-Space Model and UNet++

Qian Jiang[1], Qianqian Wang[1], Xin Jin[1]*
Michał Woźniak[2], Shaowen Yao[1], Wei Zhou[3]*

[1]School of software, Yunnan University, Kunming, Yunnan, China
[2]Faculty of Information and Communication Technology, Wroclaw University of Science and Technology, Wroclaw, Poland
[3]School of Engineering Yunnan University, State Key Laboratory of Vegetation Structure, Function and Construction (VegLab), Kunming, Yunnan, China
jiangqian_1221@163.com, qianqianwang1325@163.com, xinxin_jin@163.com, michal.wozniak@pwr.edu.pl,
yaosw@ynu.edu.cn, zwei@ynu.edu.cn

Experimental results

Comparative Experimental results

The comparative experimental results on QuickBird, GF2 and RSSCN dataset are shown as Tabel 1- 2. From these tables, while MFmamba may be slightly inferior in a few metrics, it achieves the best overall performance. This demonstrates MFmamba's superiority in jointly accomplishing SR and spectral recovery tasks. It also indicates that MFmamba excels at extracting details and critical information in remote sensing images, enhancing feature recovery performance. And from these table data, it can be seen that the performance of using the SR model first and then the colorization model is better than using the colorization model first and then the SR model, indicating that the order of use of the SR model and colorization model also has an significant impact for the experimental results.

Table 1: Experimental results on RSSCN7, black bold font marks the best performance.

Method	PSNR↑	SSIM↑	MSE↓	MAE↓	SAM↓	LPIPS↓
MBPRR(Jin et al. 2024)	29.556	0.915	89.134	118.706	0.042	0.108
CASR(Liu et al. 2022)	29.187	0.911	94.742	91.132	**0.044**	0.112
RSI(Feng et al. 2022)	33.079	0.918	65.846	93.199	0.067	0.063
CSRDNN(Feng et al. 2021a)	33.113	0.929	42.972	112.469	0.061	0.049
HAT(Chen et al. 2023)+CIR(Feng et al. 2021b)	24.406	0.636	320.079	126.133	0.163	0.139
CIR(Feng et al. 2021b)+HAT(Chen et al. 2023)	24.652	0.697	269.313	125.943	0.154	0.477
SwinIR(Liang et al. 2021)+CIR(Feng et al. 2021b)	24.438	0.639	317.605	123.530	0.162	0.133
CIR(Feng et al. 2021b)+SwinIR(Liang et al. 2021)	24.652	0.697	269.305	125.834	0.154	0.478
Ours	**35.710**	**0.948**	27.288	82.338	0.047	**0.047**

More Visualization of Comparative Experiments

To better illustrate our experimental results, we selected five images from each dataset to compare the performance of

several existing methods with our proposed MFmamba, as shown in Figs. 1–2. The 'Error Intensity' in the last column represents the error intensity between the generated results of our model and the label. The color changes gradually from blue to red. Among them, blue represents the area with relatively small errors, while yellow and red represent the areas with relatively large errors. From these figures, it is evident that MFmamba enhances spatial resolution, generating output images with higher resolution than the input images. Additionally, MFmamba improves spectral resolution, as its colorized results closely match the color information of the MS images. The absence of artifacts and edge blur in the output demonstrates that MFmamba accurately recovers spatial resolution. For example, in the Potsdam dataset (Fig. 1), most comparison methods struggle to colorize the orange roofs correctly. Although MBPRR and RSI can successfully colorize the roofs, they are still blurry compared to MFmamba. In contrast, MFmamba provides the correct color for orange roofs, significantly improving spatial resolution.

References

Chen, X.; Wang, X.; Zhou, J.; et al. 2023. Activating more pixels in image super-resolution transformer. In *ICCV*, 22367–22377.

Feng, J.; Jiang, Q.; Jin, X.; et al. 2021a. CSRDNN: An Integrated Scheme for Single Satellite Image Colorization and Super-Resolution Using Deep Neural Networks. In *IJCNN*, 1–9.

Feng, J.; Jiang, Q.; Jin, X.; et al. 2021b. Remote sensing image colorization based on deep neural networks with multi-scale residual receptive filed. *Journal of Computer-Aided Design & Computer Graphics*, 33(11): 1658–1667.

Feng, J.; Jiang, Q.; Tseng, C.-H.; et al. 2022. A deep multitask convolutional neural network for remote sensing image super-resolution and colorization. *IEEE Transactions on Geoscience and Remote Sensing*, 60: 1–15.

Jin, X.; Liu, L.; Ren, X.; et al. 2024. A Restoration Scheme for Spatial and Spectral Resolution of Panchromatic Image

---

*Corresponding authors.

Table 2: Contrast experiments results on QuickBird and GF2, black bold font marks the best performance.

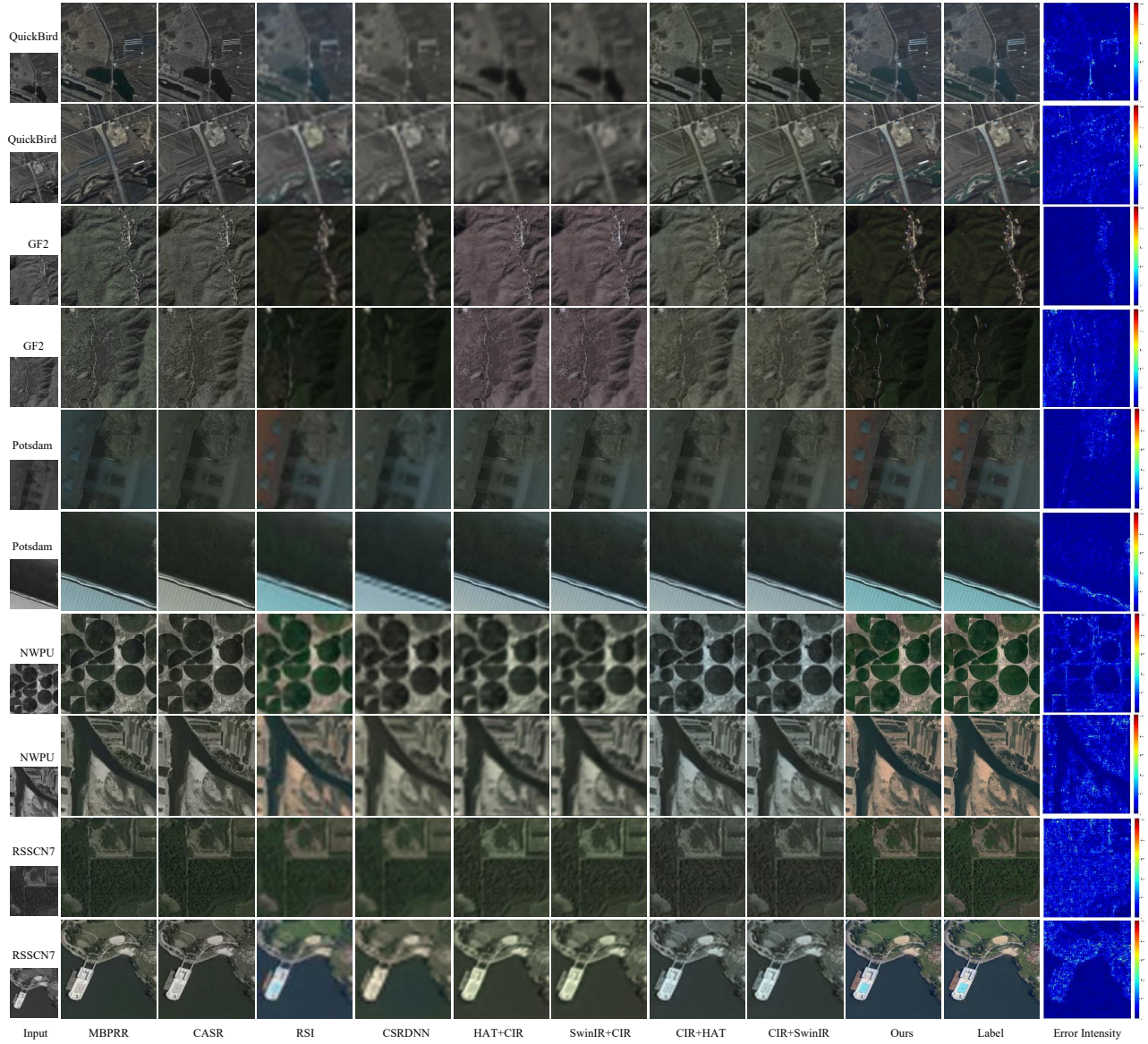| Method	QuickBird Dataset						GF2 Dataset					
	PSNR↑	SSIM↑	MSE↓	MAE↓	SAM↓	LPIPS↓	PSNR↑	SSIM↑	MSE↓	MAE↓	SAM↓	LPIPS↓
MBPRR(Jin et al. 2024)	30.998	0.916	60.820	135.183	**0.034**	0.102	25.998	0.827	191.424	114.463	0.069	0.150
CASR(Liu et al. 2022)	29.839	0.905	77.081	117.433	0.037	0.142	25.463	0.803	216.026	110.224	0.074	0.194
RSI(Feng et al. 2022)	33.295	0.913	53.499	104.617	0.088	0.060	33.295	0.923	48.121	96.490	0.105	0.038
CSRDNN(Feng et al. 2021a)	32.673	0.902	49.136	107.238	0.102	0.052	32.960	0.916	53.552	108.693	0.107	0.088
HAT(Chen et al. 2023)+CIR(Feng et al. 2021b)	18.528	0.418	1287.541	150.423	0.392	0.51	14.443	0.188	2579.073	162.645	0.556	0.588
CIR(Feng et al. 2021b)+HAT(Chen et al. 2023)	18.503	0.391	1372.885	144.013	0.403	0.38	15.005	0.234	2262.869	161.467	0.546	0.571
SwinIR(Liang et al. 2021)+CIR(Feng et al. 2021b)	18.539	0.418	1285.538	159.455	0.394	0.515	14.444	0.188	2578.778	162.635	0.556	0.588
CIR(Feng et al. 2021b)+SwinIR(Liang et al. 2021)	18.506	0.391	1372.323	144.013	0.403	0.38	15.007	0.235	2262.051	161.467	0.546	0.570
Ours	**35.723**	**0.943**	**24.936**	**98.558**	0.064	**0.041**	**39.905**	**0.980**	**8.87**	**60.960**	**0.046**	**0.013**

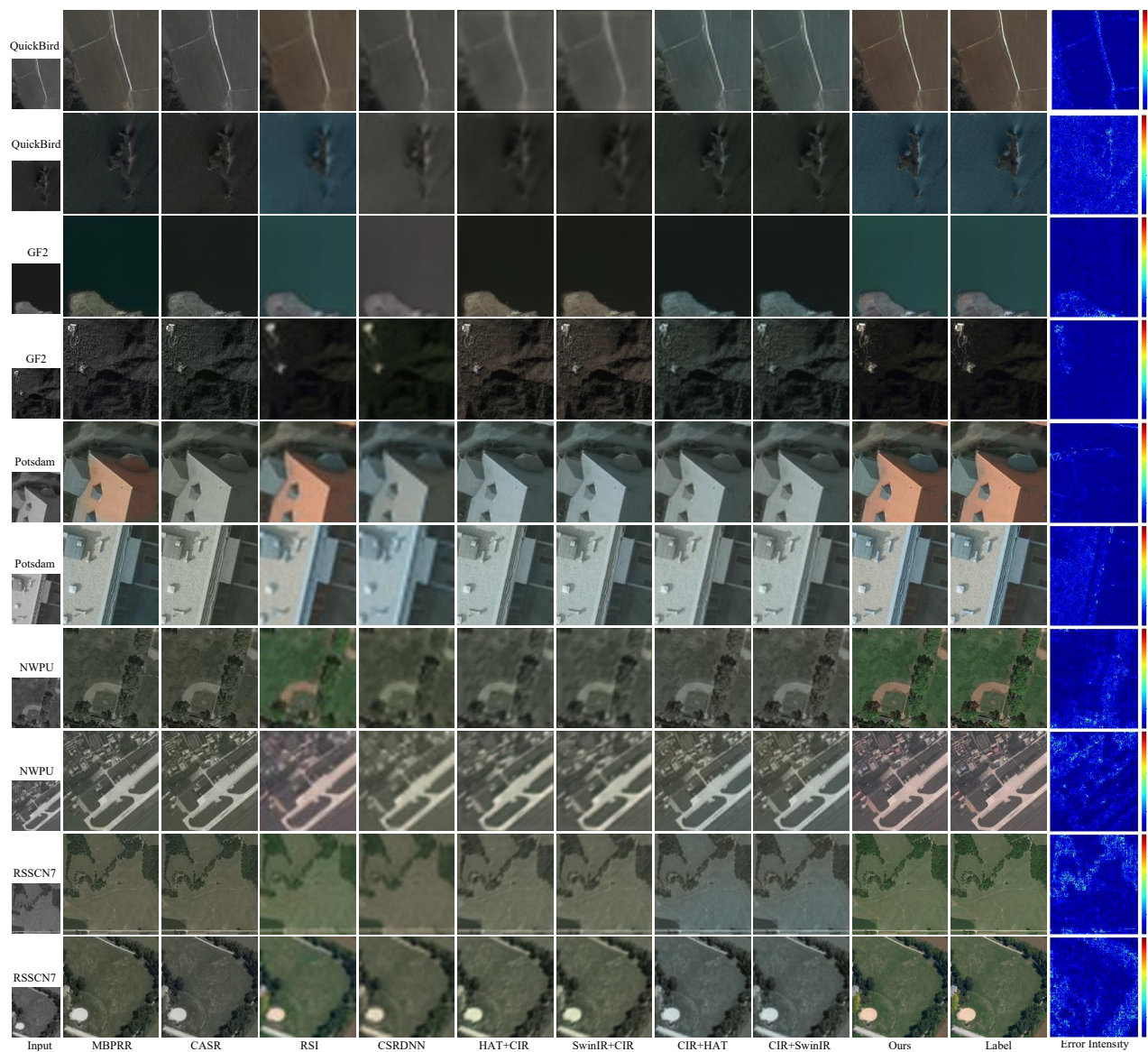Figure 1: Visual results of MFmamba and benchmark methods on five different datasets.

Figure 2: Visual results of MFmamba and benchmark methods on five different datasets.

Using Convolutional Neural Network. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 17: 3379–3393.

Liang, J.; Cao, J.; Sun, G.; et al. 2021. Swinir: Image restoration using swin transformer. In *ICCV*, 1833–1844.

Liu, L.; Jiang, Q.; Jin, X.; et al. 2022. CASR-Net: A color-aware super-resolution network for panchromatic image. *Engineering Applications of Artificial Intelligence*, 114: 105084.