Wavelet-based Fourier Information Interaction with Frequency Diffusion Adjustment for Underwater Image Restoration

Chen Zhao, Weiling Cai*, Chenyu Dong, Chengwei Hu
School of Artificial Intelligence, Nanjing Normal University

A. Supplementary materials

We have conducted an extensive analysis. Specifically, compared to UIEBD, the LSUI dataset encompasses a subset of dark images in Figure 1 (a). We discerned that GT of dark images exhibit a black background in Figure 1 (b), which could be a pivotal factor constraining the performance of WF-Diff. As shown in Figure 1 (c), a test image on the LSUI reveals that when WF-DIFF is applied to process dark regions, there is a tendency for the generated image backgrounds to assume a black hue. While our method outperforms others in terms of color restoration and detail enhancement, paradoxically, this strength turns into a limitation when confronted with extremely dark backgrounds. This is exemplified in Figure 6, where our results exhibits a darker background. Moreover, the evaluation on the U45 employed a pretrained model on the LSUI, thereby inheriting the same limitation.

Table 1 shows the real figures on the **inference speed** for WF-Diff, which shows that our model does not dominate in terms of inference time compared to recent approaches. It should be mentioned that the implicit sampling step is set to 10 for WF-Diff. In addition, Table 2 further shows the comparison of FLOPs for WFI2-net. Furthermore, we show enhancement results for different frames of **temporal sequence data** from real scenes in Figure 2-6, which exhibit surprisingly coherent consistency and achieves significant enhancement. The results of SCNet show a light blue hue, indicating a relatively weak color restoration capability; the results of the Ushape and DM-water have a low contrast and an overall tendency to be whitish. On the contrary, our results are closer to the real world in terms of color restoration and detail enhancement.

Table 3 shows the **overall ablation study** of WF-Diff. We mainly explore the impact of $\mathcal{L}_h$, $\mathcal{L}_a$, low-frequency diffusion branch (LDFB) and high-frequency diffusion branch (HDFB) on the overall performance of WF-Diff (Restricted by time and space of rebuttal). It is clear that the $\mathcal{L}_a$ has the greatest impact on the overall performance of WF-Diff, and HDFB has a greater ability to adjust details than LDFB. In addition, Table 4 further shows the adaptability of FRDAM across different methods.

*Corresponding Author. E-mail: caiwl@njnu.edu.cn

Table 1. Comparison results of inference speed.

Method	SCNet	Ushape	DM-water	WFI2-net	WF-Diff
Inference time(s)	0.0149	0.0353	0.1441	0.0739	0.2816

Table 2. Comparison results of FLOPs.

Method	SCNet	WaterNet	Ucolor	Ushape	WFI2-net
FLOPs(G)	5.88	193.7	443.8	66.2	94.1

Table 3. The overall ablation study of WF-Diff on UIEBD.

Method	w/o $\mathcal{L}_h$	w/o $\mathcal{L}_a$	w/o LDFB	w/o HDFB	WF-Diff
PSNR	22.16	21.48	22.58	22.32	23.86

Table 4. Ablation study with the FRDAM on UIEBD.

Method	Unet	SCNet	Ushape
w/o FRDAM(PSNR/SSIM)	17.41/0.7769	20.41/0.8235	21.25/0.8453
w FRDAM(PSNR/SSIM)	20.23/0.8144	21.69/0.8571	22.47/0.8643

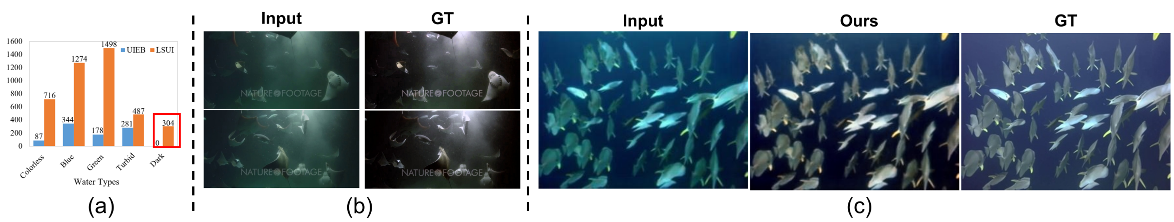

Figure 1. Analysis and Discussion.

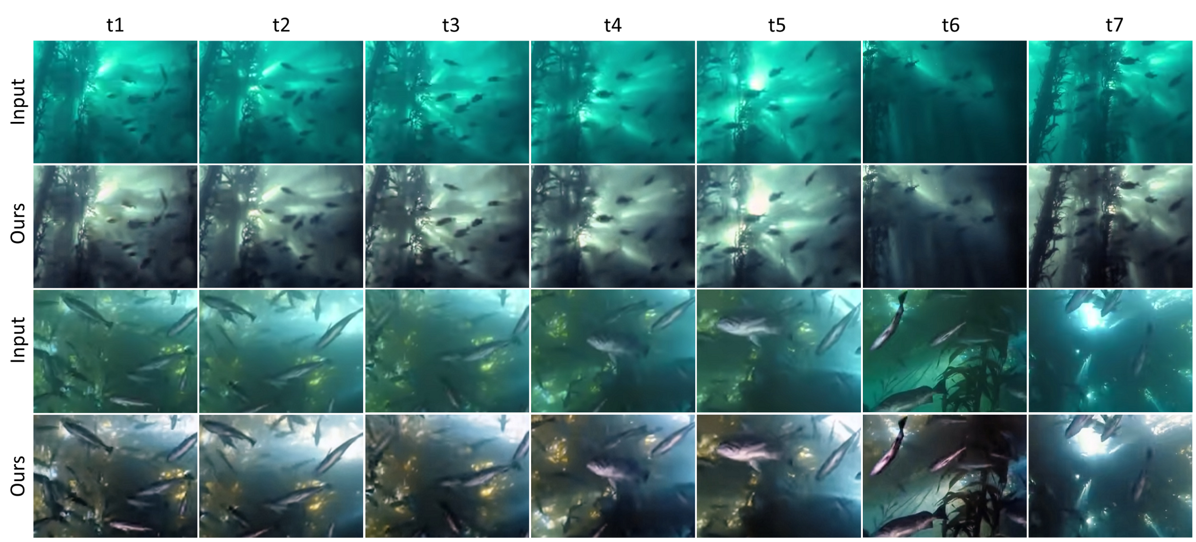

Figure 2. More visual results from real-world scenarios.

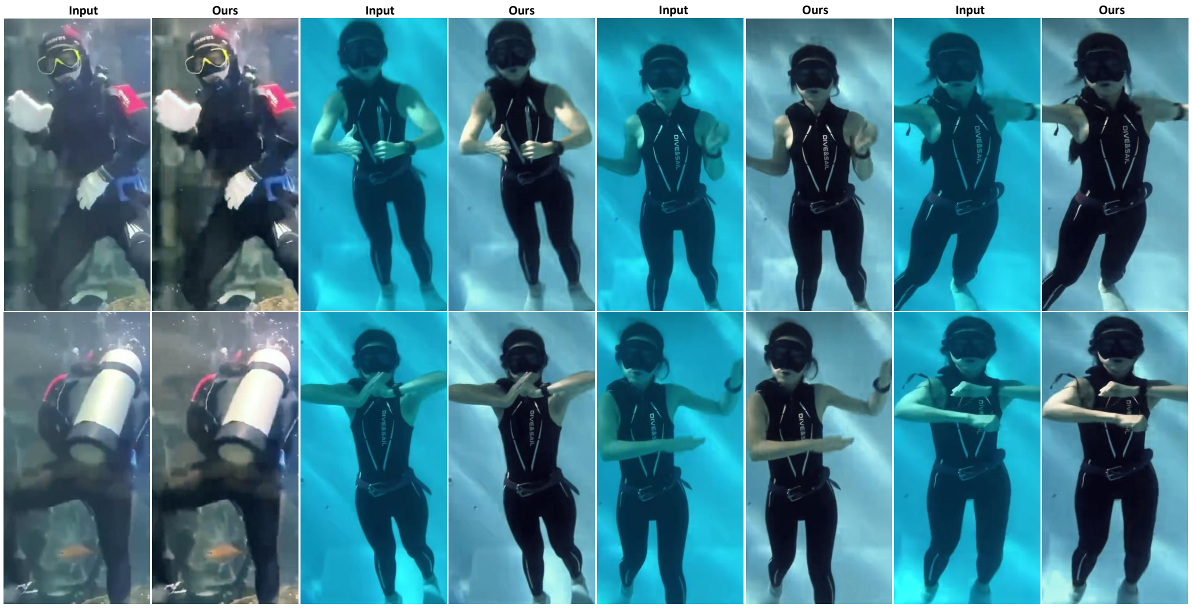

Figure 3. More visual results from real-world scenarios.

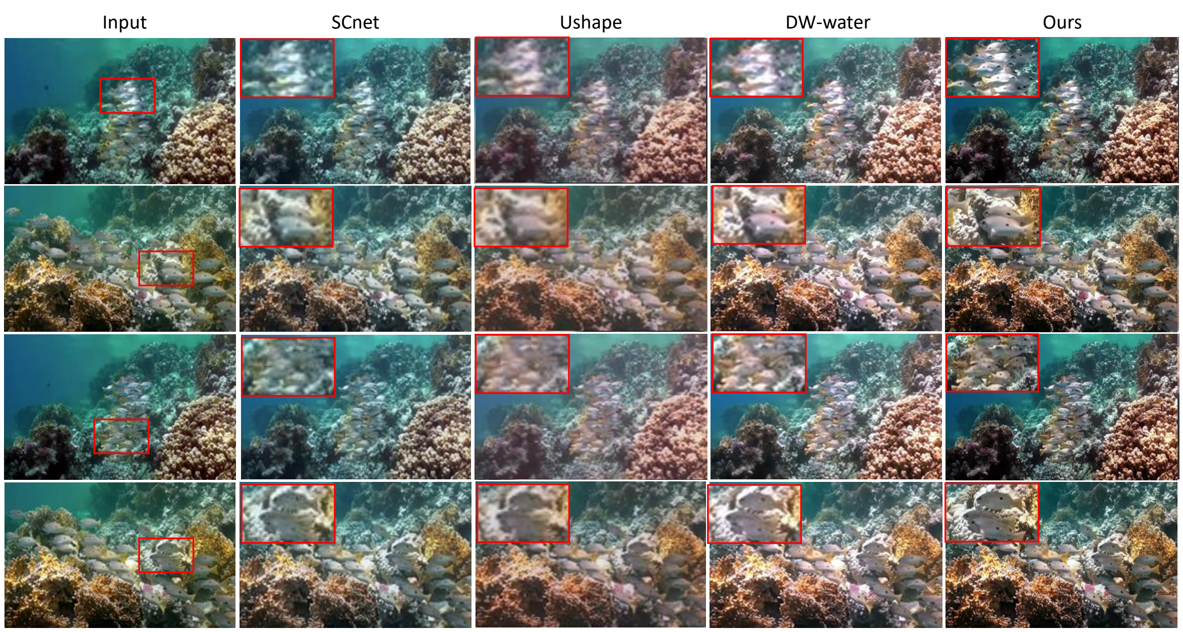

Figure 4. More visual results from real-world scenarios.

Figure 5. More visual results from real-world scenarios.

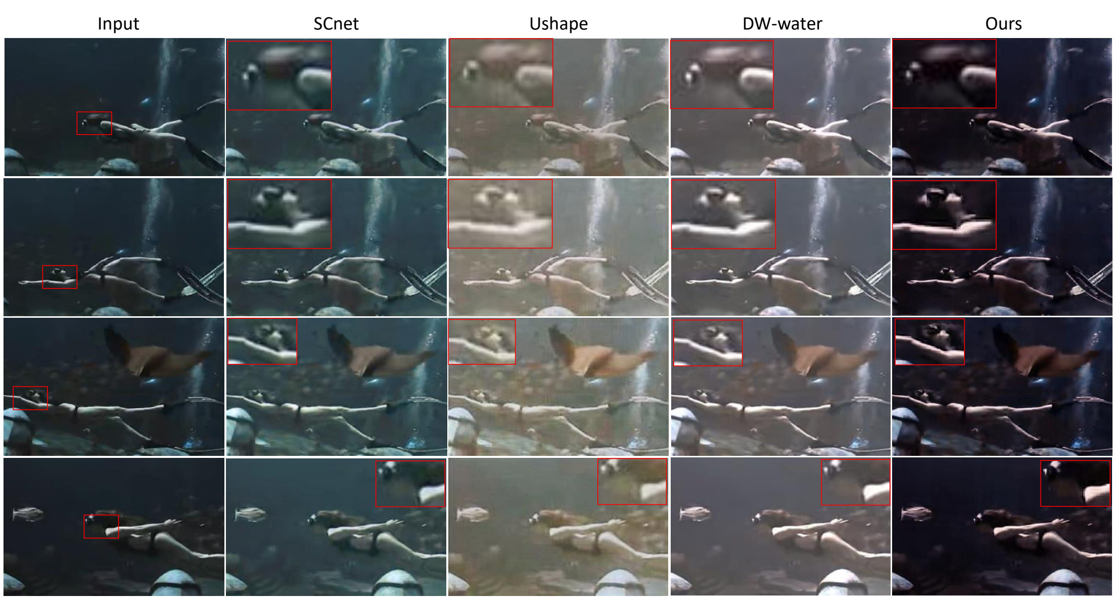

Figure 6. More visual results from real-world scenarios.