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#3159

Retinex Underwater Image Enhancement With Multiorder Gradient Priors

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1. Introduction

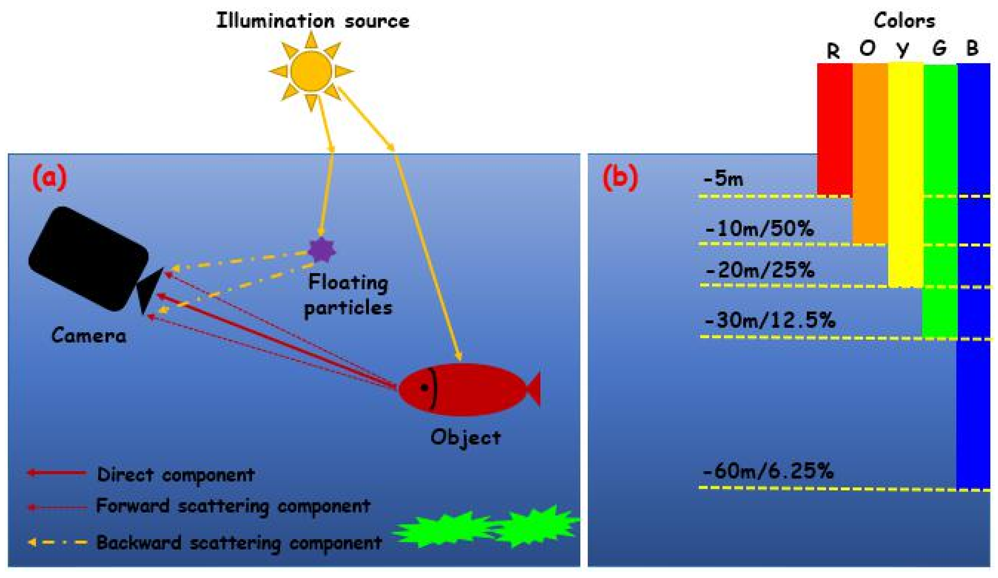


Figure 1. Schematic diagrams of underwater imaging model (a) and light absorption (b).

Due to complicated physical property of underwater image environment, underwater images suffer from **color distortion and contrast degradation** when light travels in water.

2. Motivation

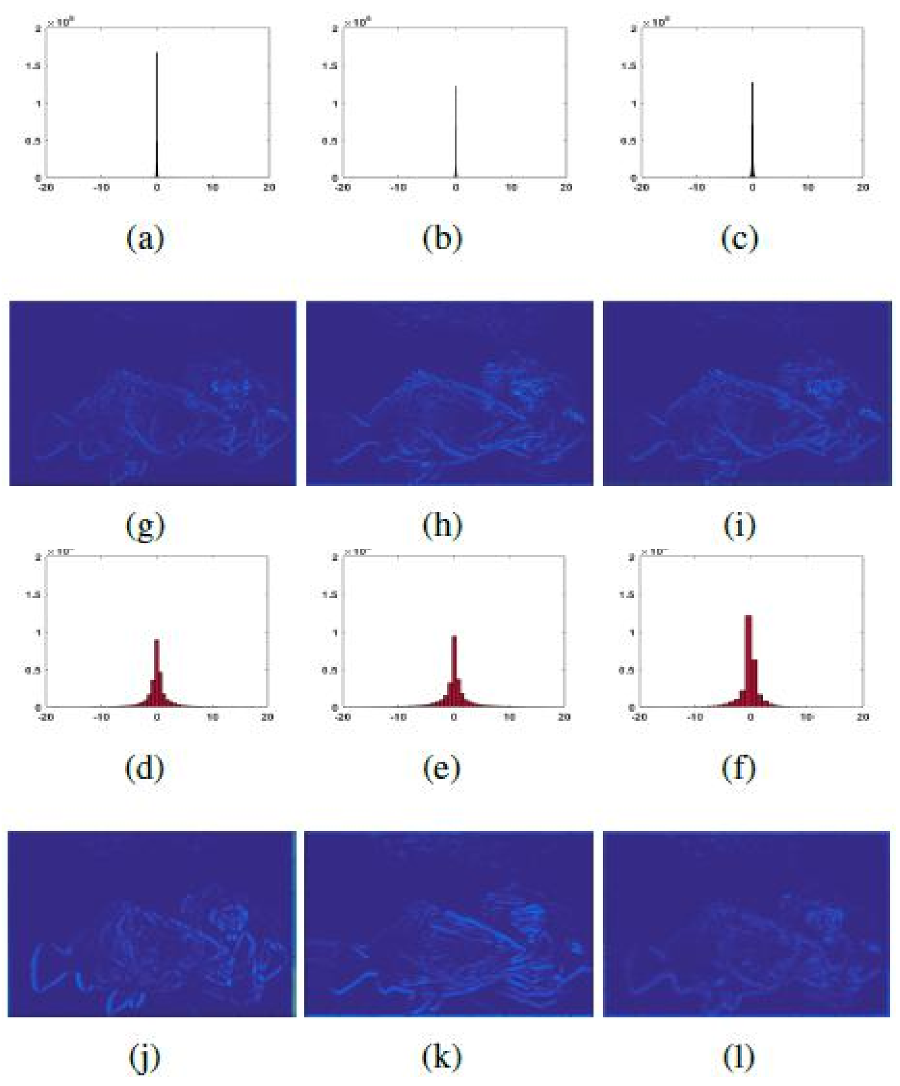


Figure 2. Average multi-order gradient histograms of reflectance (a-c) and illumination (d-f) on 100 high quality underwater images. (a)(b) and (d)(e): average histograms of first-order gradients of reflectance and illumination at horizontal and vertical directions. (c) and (f): average histograms of second-order gradients of reflectance and illumination.

Note that **multi-order gradient histograms of the reflectance (a-c) are more sparse than those of the illumination (d-f).** Meanwhile, take one image for example, it is observed that **first-order (j-k) and second-order (l) gradients of the illumination are relative smoother than first-order (g-h) and second-order (i) of the reflectance.**

3. Proposed Method

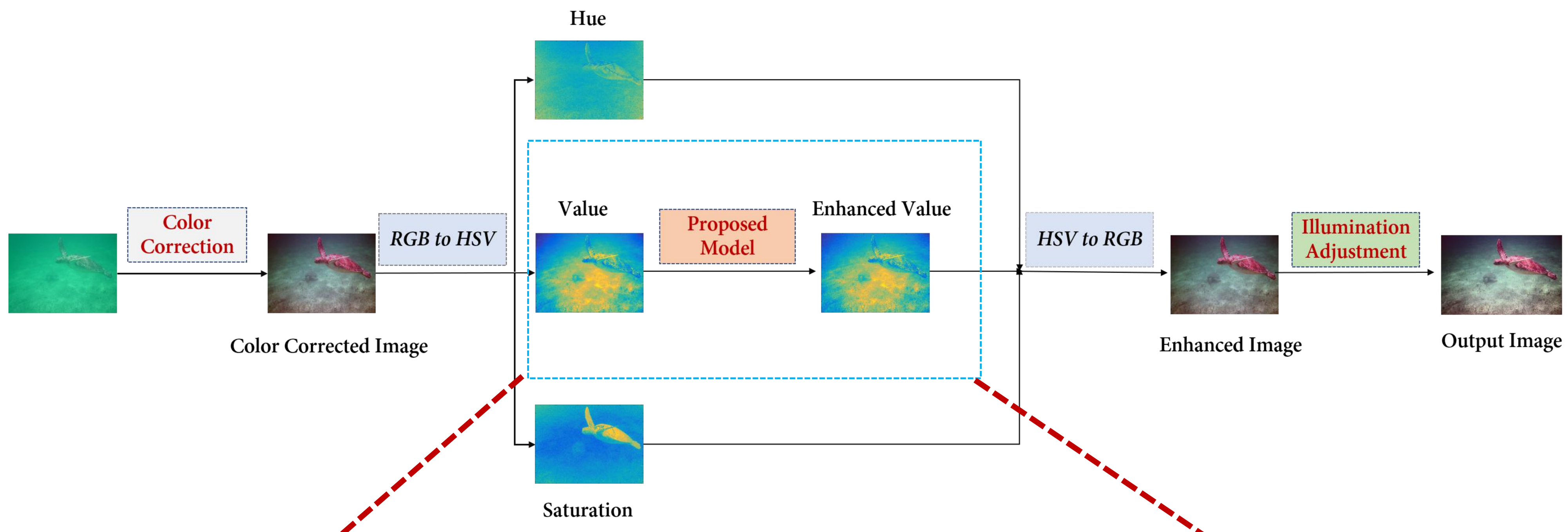
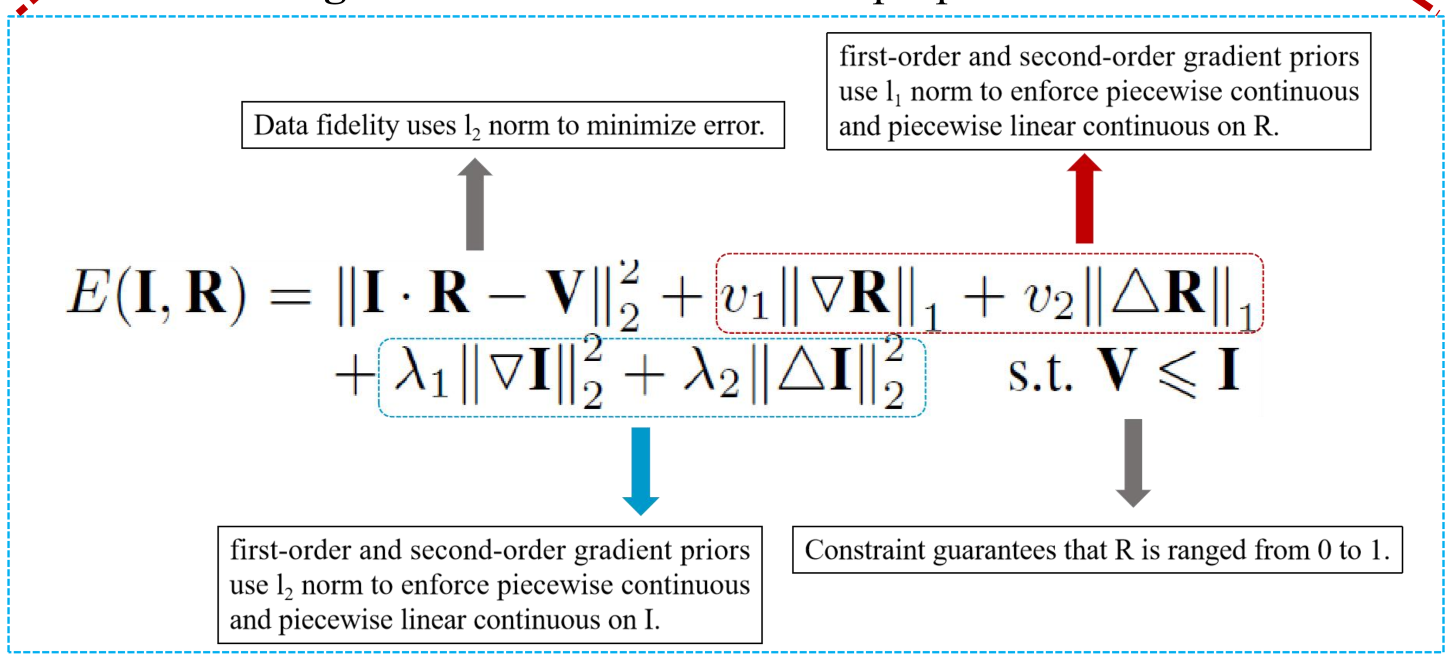


Figure 3. The flowchart of the proposed method.



$$E(\mathbf{I},\mathbf{R}) = \|\mathbf{I}\cdot\mathbf{R}-\mathbf{V}\|_2^2 + v_1\|\nabla\mathbf{R}\|_1 + v_2\|\triangle\mathbf{R}\|_1 + \lambda_1\|\nabla\mathbf{I}\|_2^2 + \lambda_2\|\triangle\mathbf{I}\|_2^2 \quad \text{s.t. } \mathbf{V}\leqslant\mathbf{I}$$

4. Results

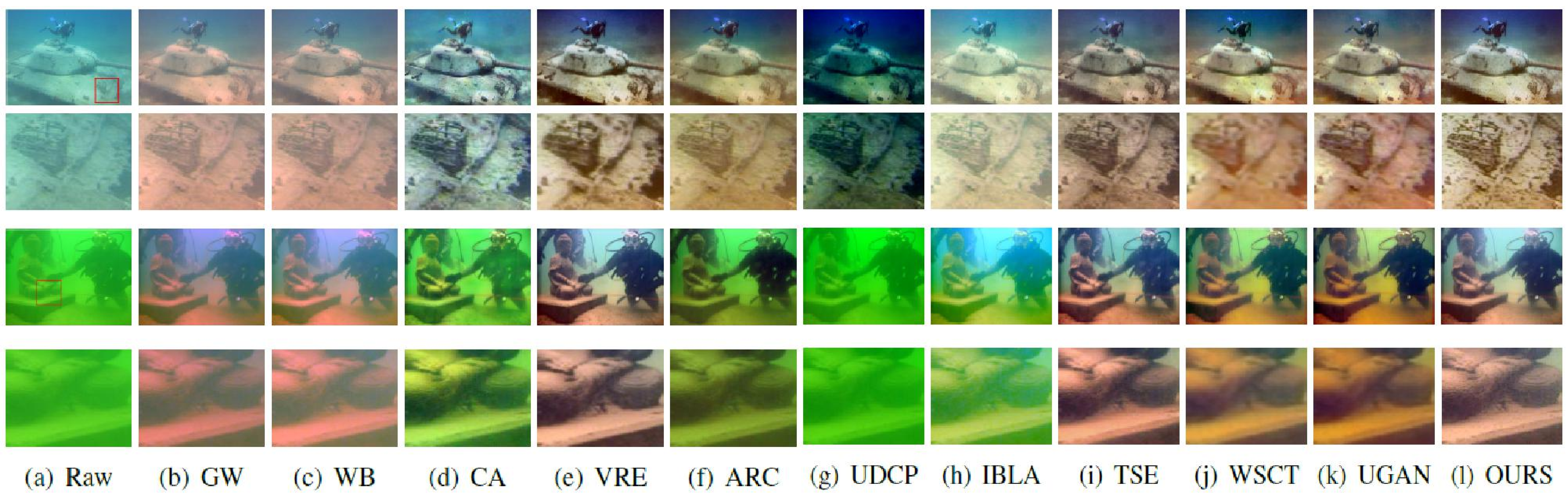


Figure 4. Enhanced and zoomed-up results of different methods.

Table 1. Average metrics on 50 underwater images

Methods	UIQM ↑	UIConM ↑	UICM ↑	UCIQE ↑	CCF ↑
GW	3.0056	0.4743	-8.3827	0.5115	18.5482
WB	3.0168	0.4705	-7.1783	0.5092	18.1135
CA	2.4496	0.7123	-64.154	0.5246	16.2955
VRE	4.1724	0.6976	-1.8649	0.5724	37.1042
ARC	2.7998	0.6269	-36.240	0.5422	16.3227
UDCP	2.2087	0.6386	-52.541	0.4745	20.9495
IBLA	3.8097	0.5498	-0.2852	0.5686	32.7881
TSE	3.4320	0.6662	-23.336	0.5334	22.4793
WSCT	2.2766	0.6426	-60.083	0.5659	16.8319
UGAN	4.0091	0.6278	**3.3558**	0.5728	20.8231
OURS	**4.4722**	**0.7209**	1.3907	**0.5730**	**37.1664**

5. Conclusion

① A variational retinex model with **multi-order gradient priors of reflectance and illumination** is proposed for underwater image enhancement, which captures fine-scale and complete structures of underwater images.
② **L_1 norm** is accurate to model multi-order gradients of the reflectance, since its multiorder gradients are **more sparse** than those of the illumination. **L_2 norm** is used to model multi-order gradients of the illumination, since its multiorder gradients are **smoother** than those of reflectance.
③ A complex underwater enhancement issue is turned into simple subproblems that their **convergence proof** is provided, and an **efficient alternating optimization** method is derived to address them, along with fast pixel-wise operations and no extra underwater prior knowledge.

Contact

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More details can be found in **https://github.com/zhuangpeixian/Supple**