Light Field Image Restoration for Vision in Scattering Media

Vigil Varghese, Donald G. Dansereau, Mitch Bryson, Oscar Pizarro, Stefan B. Williams
Australian Centre for Field Robotics (ACFR), The University of Sydney, Australia

We propose a light field imaging approach to model and remove backscatter in underwater imaging in order to recover high-fidelity images

Main contributions

- Underwater image restoration pipeline using adaptive depth-selective light field filters
- Robust technique for handling high turbidity in underwater images for a variety of object depth ranges

1. Hyperfan (HF) volume filtering

HF filter is a volumetric depth selective filter

$$H_{HF}(\omega, \theta) = H_{HC}(\omega, \theta)\, H_{DF}(\omega, \theta), \text{ where}$$

$$H_{HC}(\omega) = \exp\left(-\left[\frac{(\omega_s w_v - w_t w_u)}{\beta^2{}_{HC}/\sqrt{2 ln 2}}\right]^2\right) \text{ and}$$

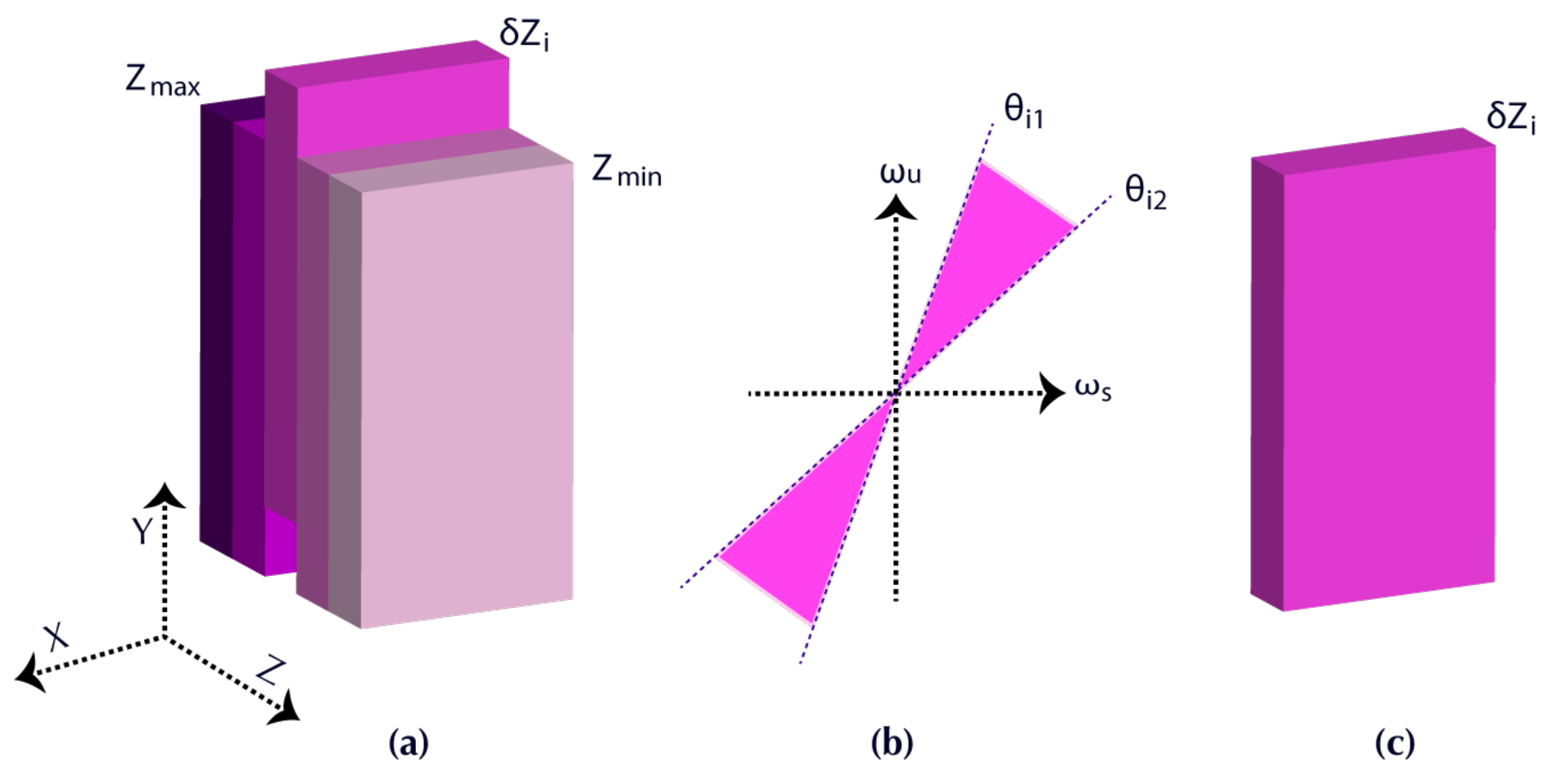
$$H_{DF}(\omega, \theta) = H^{2D}_{FAN}(\omega_s, \omega_u, \theta_1, \theta_2)\, H^{2D}_{FAN}(\omega_t, \omega_v, \theta_1, \theta_2)$$

2. Adaptive 4D depth filtering

- LF depth volume is swept from θ_{min} to θ_{max} and the volume with maximum variance is considered as the final depth volume
- Focus measure, $\emptyset(x, y)$, is applied over a windowed region $\Omega(x, y)$ of the depth volume

$$\emptyset(x, y) = \frac{1}{N^2} \sum_{(i,j)\in\Omega(x,y)} (I(i,j) - \mu)^2$$

- Hyperfan filter is applied to the input LF with the known θ_{i1} and θ_{i2} values to render a focussed frame



(a) (b) (c)

3. Backscatter model estimation

- Focus map is derived by applying the grey level local variance focus measure, which is thresholded to determine the backscatter components
- Estimated backscatter pixels are used to fit a polynomial surface

4. Image restoration

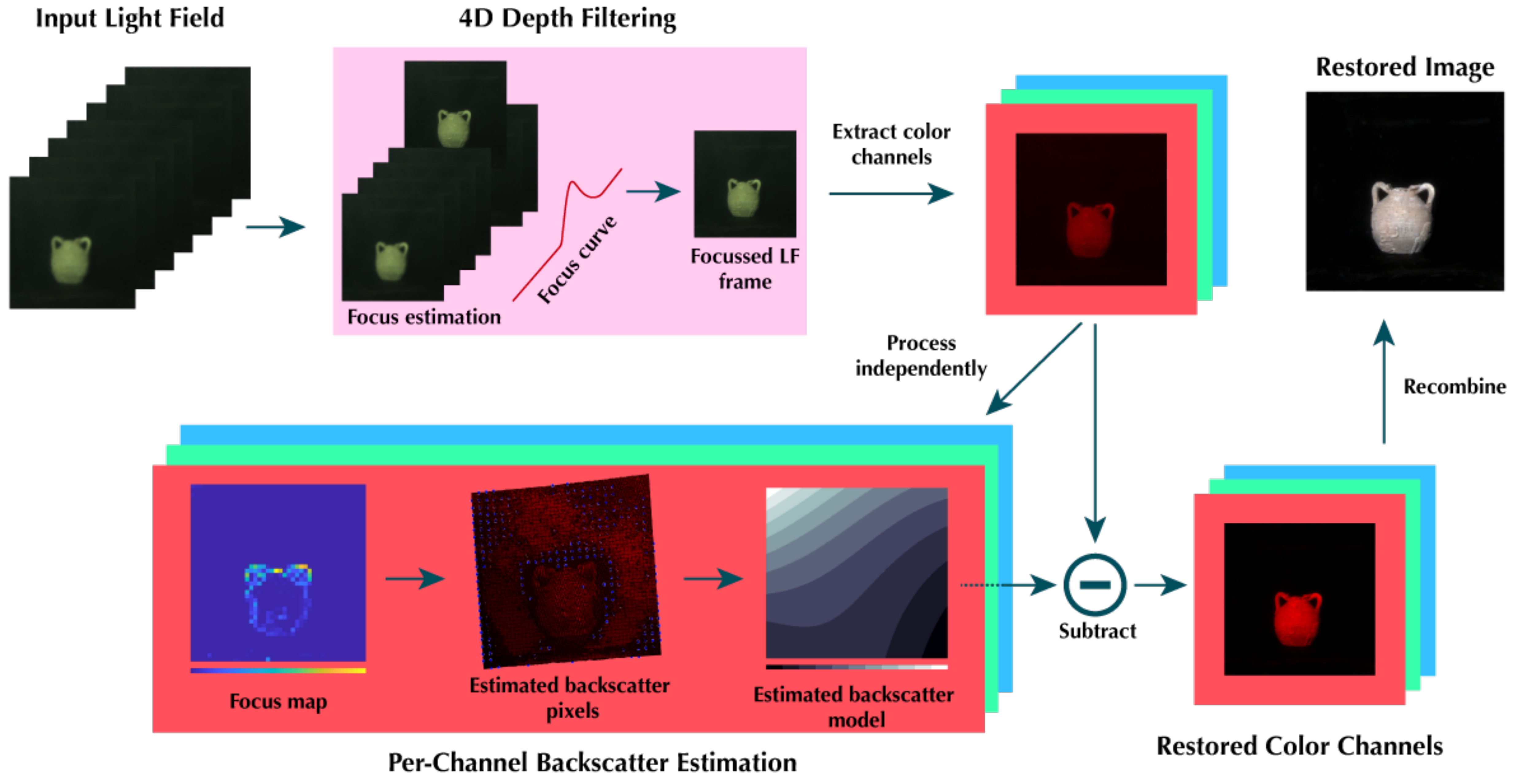
Estimated backscatter is subtracted from the captured image

Spearman correlation coefficient

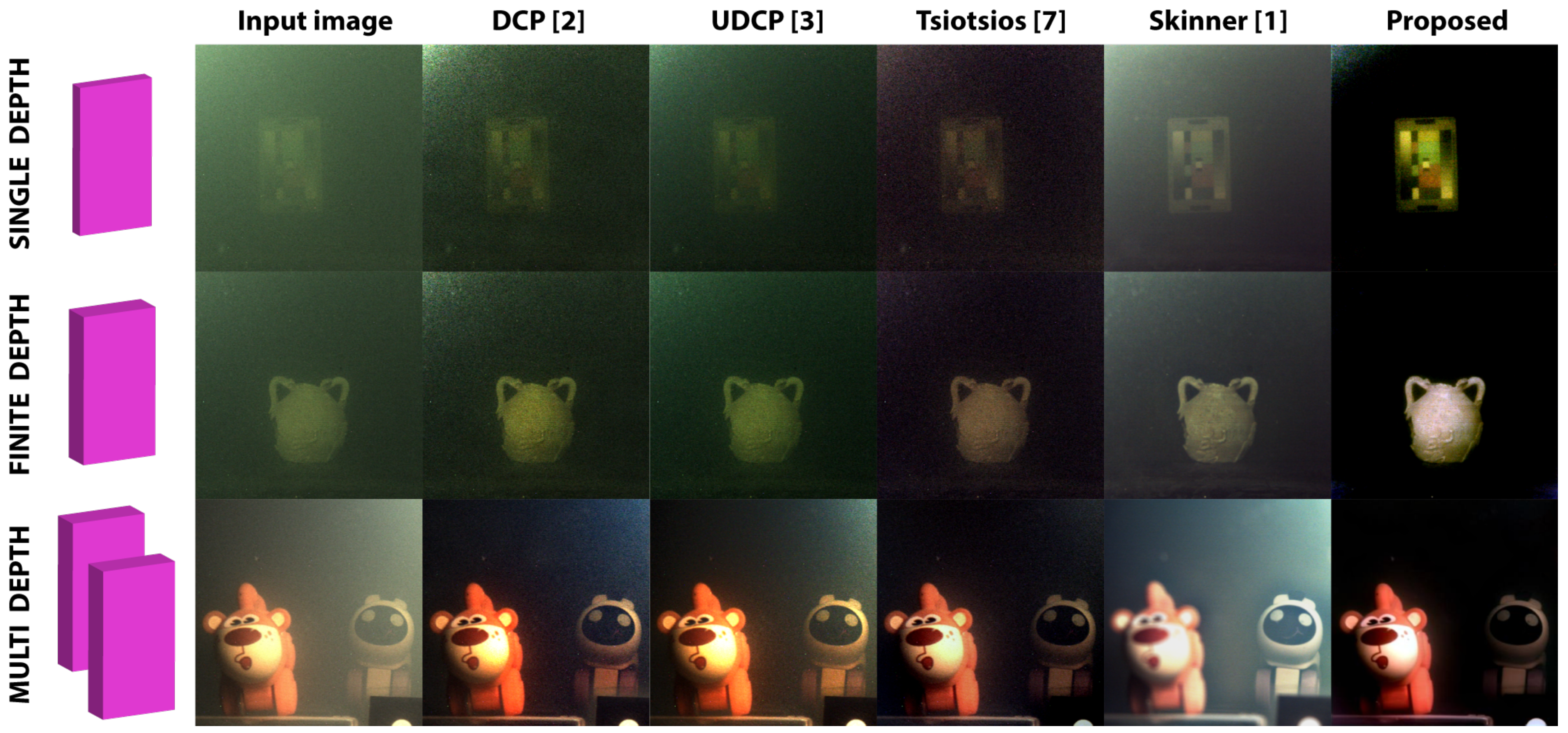
	Red	Green	Blue
Input image	0.8039	0.7295	0.2341
DCP [2]	0.8526	0.7866	0.3348
UDCP [3]	0.8460	0.7535	0.1603
Tsiotsios [7]	0.8854	0.8059	0.3411
Skinner [1]	0.8971	0.8036	0.5058
Proposed	**0.9407**	**0.8799**	**0.6259**

By adaptively filtering the light field volume to restrict its depth range around the object of interest we significantly reduce the effects of backscatter and occlusion.
The proposed method works well under highly turbid conditions.

Image restoration pipeline



Comparison of image restoration techniques



[1] Katherine A Skinner and Matthew Johnson-Roberson, "Underwater Image Dehazing with a Light Field Camera," in *2017 IEEE Conference on Computer Vision and Pattern Recognition Workshops.*
[2] Kaiming He, Jian Sun, and Xiaoou Tang, "Single image haze removal using dark channel prior," in *2009 IEEE Conference on Computer Vision and Pattern Recognition Workshops.*
[3] P Drews Jr, E do Nascimento, F Moraes, S Botelho, and M Campos, "Transmission Estimation in Underwater Single Images," in *2013 IEEE International Conference on Computer Vision Workshops.*
[7] Chourmouzios Tsiotsios, Maria E Angelopoulou, Tae Kyun Kim, and Andrew J Davison, "Backscatter compensated photometric stereo with 3 sources," in *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition.* London, UK, Jan. 2014.